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HONORABLE MENTION, 1897.

From little spark may burst a mighty flame.—*Dante.*

A PROPOSED UNIFORM COURSE OF INSTRUCTION FOR THE NAVAL MILITIA.

By H. G. DOHRMAN, Associate Member U. S. Naval Institute.

The officers who have been detailed by the Navy Department to report on the efficiency of the different naval militia organizations have rendered practically an unanimous report as to the great value of this new factor in our national defense. Though in many cases there is a wide divergence of opinion as to the proper field of action for these new organizations, yet the opinion is universal among officers who have had actual experience with the naval militia, that their field is a wide and important one, and their value great enough to justify some systematic course of instruction, that the existing organizations may be made the genesis of a thoroughly practical and reliable force of trained men, to whose care may be safely intrusted the lesser problems of the naval defense of the nation.

With the variances of view of the three generally accepted schools of opinion we have nothing to do, it will be sufficient to say that the ideal organization should be capable alike of deep sea and great gun service; of the suppression of the various

local and State disorders; should possess the greatest possible knowledge of local waters and harbors, together with the means for their naval defense, and in the preparation and manning of the auxiliaries of the fleet; though it is very likely that their greatest field of usefulness may be found to be in the direction of the last named.

A careful review of the reports of all officers who have been detailed since 1892 on naval militia inspection duty shows that they unite in stating that the men of the naval militia, as a class, are readily amenable to discipline, are above the average physically and mentally, and are actuated by a high degree of patriotism and enthusiasm.

Doctors, lawyers, professors and other men of learning and distinction in civil life are found among the members; nor will this distinction as civilians be any more of a barrier to the loyal performance of their military duty, whatever or wherever it may be, than is was to the thousands of their brethren who shouldered their muskets and marched to the front in '61.

The plan of action that has been most generally approved by the officers who have given the matter any thought contemplates the thorough training of the naval militia in infantry and artillery tactics; in boat drill and general longshore work; in torpedo work and mining; in the handling of such ordnance as is best adapted to the arming of the auxiliary navy; in signaling; in the preparation of such maps, charts and topographical information in regard to their respective localities as will best facilitate the solving of the problems of coast defense; in the preparation of the necessary plans for the speedy mobilization of the auxiliary fleet, etc.

We are then, probably, practically assured of the proper scope of these organizations; but how they may be best trained and thoroughly fitted for the manifold duties that will be required of them is another, and as yet unsolved problem. It is true that the Naval War College and the Association of the Officers of the Naval Militia have done much towards systematizing the present methods of instruction, and the Navy Department towards securing uniform legislation in the various States; the wonder is that they have accomplished so much with so little to work upon.

It is practically true to-day, however, that the *exact* status of the naval militia has yet to be established and a uniform system of instruction formulated.

There exists at present in several of the States, notably Iowa, a very complete system of instruction for the use of the National Guard, and these systems are in practical and successful operation.

The manifold, complex, and, in many cases, unaccustomed duties required of the naval militia organizations require for their successful teaching to the personnel, a degree of technical knowledge and special training in their instructors that can be acquired only by actual practice, and which we cannot expect to find outside of the ranks of the officers of the regular navy.

It has been my good fortune during the past few years to have some personal knowledge of the naval militia organizations of several of the different States, and in many cases I have inquired of the members what they expected their duties to be in case of a possible war. Almost without exception there was a general vagueness and haziness of reply that betokened a woeful lack of a definite direction in their instruction. It is true that this was no fault of either officers or men, for even now the fog that has enshrouded all naval militia matters is only beginning to lift.

If the naval militia is of any value, and there seems to be no question on this point, it is certainly time that some concerted effort be made to clear up the general uncertainty and vagueness that hangs over the whole matter and give the organizations a fair chance. They cannot be expected to properly fit themselves to perform duties in the event of a possible war if they do not know beforehand what these duties are to be.

Let a board be appointed, to consist of say three officers of the regular service and two of the most experienced of the officers of the naval militia, officers who understand alike the limitations and the capabilities of their men and know just about what to expect of them.

Let this board act in conjunction with the War College. Let them carefully weigh all evidence and suggestions, and then, after due deliberation, formulate some plan of action, some systematic and adequate system of instruction that will send the men to the front, if their services are ever needed, with a clear conception of what is required of them.

It seems to me that there is only one way to accomplish this end, and that is, after some such board as that suggested has

finally settled upon a system, to establish a bureau composed of a small detail of officers of the regular service, whose duty it would be to deliver lectures and such other practical and theoretical instructions to the various organizations as may be considered advisable. It will probably be objected by some that almost all of the younger officers of the navy are afloat and that those of advanced rank and age would not care to accept the hardships of travel incident to such service, and that therefore it would be impossible to secure such a detail; and much of this is probably correct. But if the proper training of a reserve force of 3000 or 4000 men is not of sufficient importance to secure the detail by the Government of three or four officers to properly instruct them, it is high time that the naval militia organizations were disbanded, as useless barnacles on the hull of the ship of state.

The outline of a course based upon this proposed system of instruction is appended herewith. As will be noticed, the instruction of all officers of commanding rank is preferably given at the War College, and, failing in this, under the care of an officer detailed from or under the direction of said college.

If all of our naval militia officers were millionaires, with ample leisure time at their disposal, it perhaps would not be necessary to look further into the project, for the problem would be solved.

Officers so situated could devote a summer to the course at the War College, and then be amply qualified to give all necessary instruction to the subordinates of their respective commands, for as a rule the officers of commanding rank are ex-officers of the Navy and therefore need but a little brushing up now and then to keep fully up to the requirements of the times. However, it is sad, but unfortunately true, that the commanding officers have neither unlimited time nor unlimited cash at their disposal, and generally a thorough course at the War College is an impossibility; but granting the time and the necessary cash, there still remains the further objection that the administrative and executive duties required of the commander are often of a nature to interfere seriously with the careful consideration of the problems of naval warfare, whose study would be a necessity to one who was about to act as an instructor to others.

If it were possible to fully instill into the minds of the officers commanding the mass of information necessary to make them capable instructors, and furnish them with sufficient material to

demonstrate practically, there is no reason why the very excellent plan of Iowa's School of Instruction for Officers of the National Guard could not be adopted with great profit by our naval militia organizations. However, modern naval warfare has introduced such a variety of complicated machinery, such a mass of technical detail to be mastered before one can be fully competent to instruct others, that I doubt seriously whether we have any officers in the naval militia, who have business affairs of any consequence to look after, who are competent to fulfill the requirements, able men as most of them are. They simply cannot afford to give the time necessary. As it is, many of them allow their administrative duties alone to make serious inroads upon time that should be devoted to business.

The course of instruction, as laid down in the appended chart, is intended merely as a suggestion and as showing briefly the general method proposed to be followed.

Instruction at Naval War College, or by Lecturers from Navy Department.

Captain, Commander, and Lieutenant-Commander in States having a Commander for Naval Brigade Chief.—*Course.* Practical mobilization, Naval strategy, International law, Fleet evolutions, Battle tactics and precautions, Problems of coast defense, Problems of coast defense applied to his special district, including study of transportation and supply facilities and resources, and the local topography, etc.

Instruction by Lecturers from the Navy Department.

Captain, Commander, Lieutenant-Commander, Lieutenant, Lieutenant junior grade, and Ensign.—*Course.* Maintenance of discipline, Ordnance problems, including care of the battery, direction of fire, torpedo instruction, etc., Infantry and artillery tactics, Boat and other guards, Practices and precautions of actual war, etc., Signaling, Navigation, Shore and boat exercises, Precautions to be observed in case of fire, etc., Proper provisioning and care of men on boat and shore expeditions, etc., Practical mobilization, Naval strategy, International law.

Instruction by Commissioned Officers of Division or Battalion.

Master at Arms, Boatswain's Mate, Gunner's Mate, Quartermaster, Coxswain, Bugler, Electrician.—*Course.* Infantry, artillery and boat drill, Use and care of small arms and ordnance, including direction of fire at vulnerable points of the enemy, etc., Naval ceremonies and salutes, Signaling, Familiarity with various apparatus found on shipboard, and in such other lines as may suggest themselves to the officer in charge.

Instruction by Commissioned or Petty Officers of Division or Battalion.

Seamen of the 1st class, Seamen of the 2nd class, Seamen of the 3rd class, Artificers, Yeomen, etc.—*Course.* Whatever may be considered proper by the

upon the nation to fill up the ranks of our regiments and man the guns of our navy.

The fortunes and casualties of war will inevitably place heavy burdens and responsibilities temporarily upon the shoulders of men not now in the regular service. What these will be it is of course impossible to tell, but there is no reason to doubt that these things will happen—they cannot but help happen in war prolonged for any considerable period. We cannot expect the officers upon whose shoulders these responsibilities may fall, to give a good account of themselves unless they have been properly prepared in advance to assume the duties we have reason to believe may be required of them. They cannot inspire confidence in others if they have no confidence in themselves, and this confidence only comes with a familiarity with the subject in hand born of practice or thorough study. No man can successfully cope with the responsibilities of naval command, involving the possibilities of the attack with its attendant risks, or of retreat at an inopportune time when perhaps victory was trembling in the balance and just within his grasp, or yet of passive inactivity at a time when vigorous initiative was imperative—no man can afford to take this risk, nor can the nation afford to let him take it—unless he has, by a proper course of preliminary training, proved himself worthy.

The commanding officer should be possessed not only of a fair knowledge of naval strategy, international law, and the general problems of the defense of the coast, but his knowledge of his own particular section of it should be so comprehensive as to cover all the items covered in the General Information Circular issued by the Department for the use of the naval militia last spring, and much in addition to that. He should endeavor, wherever possible, to secure the enlistment in each of his battalions, of competent draughtsmen, civil and mechanical engineers, designers and so on, in addition to the artisans generally required by law.

By so doing, not only can he obtain excellent charts of the adjacent waters, but can secure maps giving the salient points of the local topography. Further than this, he will be enabled to secure, in many cases, the structural designs of many, if not all, of the vessels that visit his territory which are suitable for conversion into auxiliaries of the fleet.

During the long winter evenings working drawings can be made for all structural changes, deck and other bracings for gun mounts, protection of machinery, construction of magazines, etc., and should include full descriptions of all machinery, boilers, etc., found on each vessel. These plans should be made and duly numbered in the case of each vessel, in sets of four, one each for the Navy Department, office of the Adjutant General of the State, Commander of State Naval Brigade, and the commander of the local battalion, where the organization of the brigade and the battalion is not identical, in which case the extra set of plans should be filed at the Navy Department. Examination of the vessels and the condition of their machinery should be made at least yearly, and such reports are to be made in the same number and manner as the plans, and should be filed with the said plans, at each of their several places of keeping.

Under the head of each vessel, in addition to the number of guns she can mount, bunker and magazine capacity, etc., should be entered the number and names of each harbor she can safely enter in the district; where coal in sufficient quantities can be obtained (the character of the coal as to steaming qualities, etc., should be noted in addition); what the loading facilities are in each place so mentioned, and the average time required to fill bunkers; the number of establishments capable of making repairs to hull, boilers and machinery—the character of such repairs and probable time required to complete same; the facilities offered for obtaining provisions and other ship supplies, including an estimate for the time required to install battery, supply magazine, provision ship, etc., ready for active service. All this and such other information as is obtainable in relation to the individual ship should be entered in two small duplicate books, said books to be filed with the Navy Department. The books should be marked with the number of the ship, which in every case should be known by number only, until such time as the mobilization of our auxiliary fleet would be required, when one copy should be forwarded to the ship's commander, who will cause same to be placed with the ship's private signal book and treated accordingly.

That the full value of this system be brought out, the whole of the nation's coast line should be apportioned into as many divisions as there are States having either sea or lake frontage,

this being done to facilitate the work of the different State naval militia organizations now in existence and of those that are yet to be authorized.

Each State in turn is to be subdivided into sections of, say, 25 miles each, the State being considered as a unit containing so many sections of the standard size.

That there may be no confusion arising from the duplication of numbers in so many different States, each section shall bear a number and be known by it regardless of the State in which the section is found. For instance, let us take the most eastern portion of the coast of Maine as a starting point. Measuring towards the west, we follow the line of the shore for 25 miles, which constitutes section one, the second 25 miles so measured in the same direction constitutes section two, and so on until the complete round of the water-bearing frontier of the nation is completed.

Roughly speaking, the coast of the State of Maine would be known as sections 1 to 14, constituting Division of Maine; that of New Hampshire as sections 15 to 17, constituting Division of New Hampshire; that of Massachusetts as sections 18 to 20, constituting Division of Massachusetts, and so on, until the round is completed. Texas might be known as sections 158 to 181, constituting Division of Texas, and Indiana as sections 200 to 204, constituting Lake Division of Indiana, prefixing Lake to such divisions as lie along the borders of our great lakes, to distinguish them from their salt water brethren.

A section or more would be assigned as the year's work of each division of a battalion, but this allotment should never be arbitrarily fixed, but, on the contrary, should be governed entirely by the difficulty of the task.

Some sections could be thoroughly covered and all needed information secured in a few days' time, while others again would require the work of months. It is understood, of course, that the sections would not be studied consecutively, but in the order of their relative value, great centers of trade and important strategic points being naturally considered first.

However, it is beyond doubt that if this system be properly adopted and its details systematically and carefully followed out, that it will furnish us with practically all the detailed information necessary for the solution of many of the problems presented by

the naval defense of our coasts, in a half-score of years or less, or at least so much of the necessary information as can be obtained by the careful study of the coast line, and is within the scope of a purely volunteer organization, with limited opportunities for actual service in many cases.

To what extent the Navy Department has recognized the value in this line of work of the Naval Militia is shown by the following extract from Secretary Herbert's report for 1895:

"The information collected by the first battalion of the Naval Militia of New York during the past summer relative to the shore line of Long Island is of such value that the Department unhesitatingly indorses the proposition to engage this corps in the study of our entire coast line. Every battalion, with proper help and direction from the Department, can, as shown by the admirable work done on Long Island Sound last summer, acquire information as to its contiguous coast that would be invaluable in case of invasion."

That the Department has recognized the value of the naval militia sufficiently to consider some uniform plan of instruction will be seen from the following from Secretary Herbert's report for 1896: "To more thoroughly instruct the Naval Militia in the duties which will be required of them in case of mobilization or of war, it is the intention of the Department to communicate to them as soon as practicable that portion of the plan of general mobilization and defense which relates to the several States to which they belong, what vessels are to be used, what positions not embraced in the military defense must be mined and protected by batteries, what signal stations must be maintained, and, in general, everything that must be done to utilize all possible resources for the local defense.

"This will be the work of years, but it is believed that by intelligent co-operation between the officers of the Department and the Naval Militia, a thoroughly digested plan of mobilization and subsequent operations may be gradually effected, which will be of inestimable value to the country."

With this in view, the Department granted permission to the officers of the Naval Militia to attend the War College and Torpedo School. Six officers followed a portion of the War College course and nineteen were instructed at the Torpedo Station during the past summer, but the very considerable expense

attached to this service obviously renders impossible the attendance of many worthy officers who are so unfortunate as to reside at a great distance from Newport.

To successfully inaugurate a system of instruction by a traveling corps of lecturers would not, I feel confident, necessitate the detail of more than four officers from their regular duties, to cover the whole of the country, including the Pacific Coast States. If the Pacific slope and possibly Texas are omitted, two officers on a properly arranged schedule can deliver four lectures apiece at each battalion headquarters within the district named during the eight months from October 1st to June 1st. This will give one lecture a month at each point, the lecturers alternating.

The proper preparation for these lectures can be arranged for by the creation of a number of small but select traveling libraries, equal in number to the points at which lectures will be delivered during the course. The libraries will be loaned by the Government to the different organizations and retained by them until the completion of the course for the year.

The composition of these libraries should be decided upon by the War College at the time of the determination of the proposed course for the current year, and should consist of such works as will enable the officers of the Naval Militia to make proper preparation prior to the delivery of each lecture. Each officer, where practicable, should be furnished with a synopsis of every lecture at least ten days prior to its delivery, and said synopsis should contain a list of the authorities to be consulted, as many of which should be embodied in the traveling library as possible, ever bearing in mind the fact that the consultation of multitudinous references is confusing to the lay reader, and for this reason the library should be very compact, containing nothing but the essential authorities on the subject-matter in hand.

Such a course of eight lectures might be made up as follows: one lecture on the general principles of naval warfare; one lecture on international law; one lecture on conduct of landing parties and general shore operations; one lecture on signaling, seeking, if possible, to secure a practical knowledge of both the army and navy codes, that the Naval Militia might act as an efficient intermediary in case of need; two lectures on the problems of mobilization, and two lectures on torpedoing and mining, illustrated by working models of reduced size, if possible.

The mere fact that promotion should be made largely dependent upon the proficiency in the various branches in the relative order of their importance would act as a powerful incentive to close application, if there were no other reasons.

It seems to me that the thorough consideration and study of such courses as this each year cannot help but largely increase the effectiveness of the Naval Militia, and when we stop a moment to think and realize the heavy burdens that must of necessity fall upon the shoulders of these men in case of a war with a first-rate naval power, we should consider very carefully before rejecting any suggestion that tends to increase the efficiency of our naval defenses.

Nowhere is the importance of the early and systematic training of the Naval Militia of more moment than in any consideration of the defense of our great lakes and in the conduct of any military operations directed against the Dominion of Canada. It is patent to any one that the construction of the various canals passing through territory under Canadian control by which vessels from the Atlantic can have untrammeled entrance to the lakes, has practically nullified, so far as Great Britain is concerned, the provisions of the well known treaty of 1817. Great as is the excess of American tonnage on the bosom of the lakes, it will be a source of weakness rather than of strength, if we are not prepared at an instant's notice to convert our peaceful merchantmen into powerfully armed and thoroughly equipped cruisers of the auxiliary fleet, capable of blockading the Canadian canals and preventing thereby the entrance into the lakes of the British squadron; or at least capable of rendering a good account of themselves in any conflicts that might occur for the supremacy. A summer's campaign in Canada would be practically impossible without the control of the lakes by our navy, and the hordes of men that are prepared at a week's notice to overrun Canada, that we hear of so often during the periodical twistings of the British Lion's tail by our zealous jingoists, we fear would suffer an unpleasant awakening from their pleasant dreams of easy conquest and cheaply won glory.

It is true that joy over the probable conclusion of a five years treaty of arbitration between the two great English-speaking nations of the world is echoing and re-echoing over England and America at this Christmastide, and far as it is from any true

lover and well-wisher of either nation to wish for anything else than the early consummation of a bond of amity between the two nations that shall forever render war between them a thing improbable if not actually impossible.

Yet we would be blind to the dictates of military prudence if we did not carefully consider the possibility of the proper defense of the nation against attacks from every quarter, regardless of present state of existing friendships. The great preponderance of the naval power of Great Britain, our long and unprotected Canadian frontier, including the defenseless cities of the great lakes, render the consideration of the possibility of attack from this direction of the most vital importance, and into any intelligent consideration of this problem, the part to be taken by the Naval Militia of the lakes is bound to be a factor of great importance.

When so much may depend on the efficiency of the Naval Militia organizations, is it not the part of prudence and wisdom to afford them every possible aid in their efforts to properly fit themselves to assist in the defense of the nation?

DISCUSSION.

Lieut.-Commander RICHARD WAINWRIGHT, U. S. N.—I have read the paper of Mr. Dohrman with great interest, and agree with him thoroughly as to the value of the naval militia organizations and the necessity for a systematic course of instruction and training.

As Mr. Dohrman states, there appears to be a wide divergence of opinion as to the proper field of action for the naval militia, and this has led not only to some uncertainty as to the proper course of training, but also served to somewhat discourage the organization. In order that the officers and men should take real interest in their work the course of instruction must be made interesting, and, above all, they must see plainly before them the useful results intended to be reached by the work. They are patriotic, and desire to see some real position of value to be occupied by them in time of war, at which their training in time of peace has been directly aimed.

The navy has no reserve *personnel* unless the naval militia is trained so as to form such reserve. All the great naval powers have large reserves upon which they can draw when it becomes necessary to mobilize their fleets. At the present time this difficulty is avoided by us, as we keep all our ships in active service; but it is manifest that this cannot continue when we have a number of vessels more nearly adequate to the needs of

the country. Then a proportion of the vessels must be placed in reserve, with small crews sufficient to keep the vessels in every way ready for immediate service. But vessels in reserve will be useless without men in reserve, for modern men-of-war require well-trained men to handle them efficiently. To furnish this reserve is, in my opinion, the most important field of action for the naval militia, and the one that they can fill most efficiently with the training possible under the conditions of their organization.

The naval militia can be trained, if reasonable facilities are offered, in the use of modern guns and how to care for them. Much of their training can be carried out ashore, so that with some little training afloat both officers and men can become competent to man the batteries of our war-ships. With a proportion of our ships in reserve, there should be a sufficient number of men to fully man the armored fleet and some of the larger cruisers and to furnish a nucleus of a crew for the remaining cruisers. To each of these cruisers a certain number of naval militia should be assigned sufficient to man all the guns, leaving the different organizations intact as far as possible. The regular crew would perform all the special seaman's duties and handle the engines, etc. When it is desirable to exercise any portion of the naval militia it should be done on the cruiser to which it is assigned. If this cruiser is in the active fleet, its shifting crew should be sent to the corresponding vessel in the reserve. If it is in reserve, it would only be necessary to march the naval militia organization on board, fill up the fire-room force and go to sea.

The next most important field that can be occupied by the naval militia in time of war is that of manning the batteries of such auxiliary cruisers as may be armed by the government. For this the same training is needed as for manning the guns of the regular cruisers.

Beyond doubt there are many other duties that may be performed in time of war by the naval militia organizations, requiring other kinds of training, some of which may prove more amusing if not as useful. There are many duties that might be pointed out pertaining to purely local defense and longshore work, some of which are pointed out by Mr. Dohrman; but such duties should be left to those organizations that are unwilling to leave their own ports or that join the organization for amusement. I much mistake the spirit that animates the present organizations which form our naval militia if they have many such men in their ranks. I believe that as a body they have formed and joined these organizations with the patriotic motive of serving their country in time of war in such positions as will be most useful. All that they require is that the proper field of action, and the training necessary to fill it properly, be pointed out to them and that it is a dignified and naval position.

Courses in strategy, tactics, coast defense, international law and navigation may all prove interesting and can do little harm if they are taken up purely as a mental stimulus without neglecting to occupy the time necessary to acquire a good knowledge of naval ordnance and gunnery. It is possible for those whose life work is in a profession or trade on

shore to become good gunnery officers or good gunners by systematic training. But it is impossible for them to become even tolerable seamen or navigators, or to acquire the skill necessary to handle a modern warship, much less to handle a fleet. Infantry drill is good discipline; some signaling knowledge would be advantageous; but the main study of the naval militia should be gunnery, and their principal exercise should be with the great guns.

While I have differed broadly from the ideas set forth by Mr. Dohrman, I believe we both have the same object, that is, to point out the honorable and useful position that should be filled in time of war by the naval militia, and the systematic course of training necessary to fit the organizations to fill this position.

There will always be many functions that can be performed in time of war by auxiliaries to the regular naval force, unless we should be more thoroughly prepared for war than seems at all likely, and some field of usefulness would be found for an organization however trained; but the most useful, the most honorable and worthy of the combined efforts of the naval militia is that of trained gunners.

Col. J. L. Carter, Assistant Inspector-General, State of Massachusetts.—It is a very gratifying sensation to feel that there are intelligent minds studying the subject of the national defense, and in no quarter is there more room for study than in the problem of the functions and scope of the new branch of our service, the naval militia. The paper under discussion—"A proposed uniform course of instruction for the naval militia"—by H. G. Dohrman, is a valuable contribution to the growing literature on this subject, and while I do not concur fully in all of the propositions which it contains, I find a great deal which is valuable and which should receive serious consideration by those to whom the operations of the naval militia are committed.

I believe that there should be a board detailed, as the paper suggests, to formulate a system of instruction and a plan of action, and that the work so formulated should be limited to the simplest possible duties consistent with proper effectiveness, because the time at the disposal of both the officers and enlisted men of the militia is very brief.

There is, I fear, too great a tendency to spend valuable summer-time work in taking down small details of coast topography which are amply covered now by the coast survey charts. Certain data are needed, it is true, connected with strategic plans, and what these are can be best determined by the Naval War College, whose calls for information should be forwarded by the Navy Department to such of the naval militia organizations as are best situated to furnish them. To this extent I concur with the essayist in his recommendation about a study of the coast.

The plan of keeping informed about the available merchant vessels for hasty conversion into armed auxiliaries I heartily endorse. In fact, I believe the manning of these vessels, especially as to their armament, is one of the duties which will be most urgently demanded of the naval militia in case of war. There are plenty of seamen in civil life who can

volunteer and man these vessels, but they would not know gunnery and could not be taught to handle the modern breech-loading rifle guns soon enough to be of use. Modern wars come quickly, and the fire burns briskly while it lasts. There is no time to teach gunnery, so let that be learned in time of peace by the naval militia, and have the men and the guns ready to place quickly aboard of our fine coastwise merchant steamers.

The suggestion that lectures be delivered by officers detailed for the purpose, though good in theory, would, I think, be of little benefit in practice. Lectures go in at one ear and out at the other, unless, as at college, one is studying text-books on the subject under treatment and is attending a systematic course throughout a whole season.

The written lectures put into print and distributed would be valuable. The more literature we have on this subject the better; there may be much chaff, but there will also be many rich kernels of grain when the winnowing is done, as the paper now under discussion shows.

Lieut. J. H. GIBBONS, U. S. N.—With the principal proposition laid down by the essayist, viz. that the naval militia must be an important factor in our national defense, and that it stands in sore need of a systematic course of instruction, every one can agree. When it comes, however, to the question of the best means to this very desirable end, the essayist seemingly ignores the "spark" and battles with the "mighty flame" of his motto.

A glance at his proposed course of instruction on page 215, especially that for commanding officers, will convince any naval officer that the ground to be gone over would take much more time than business and professional men would be able to give to such work. If a naval officer wished to become a lawyer he would not qualify by simply attending sessions of the Supreme Court. The statement that ex-officers need but a little "brushing up" to keep fully abreast of the requirements of the times will not, I am sure, be borne out by the testimony of those for whom the claim is made. I quote from the remarks of the commander of the Massachusetts Naval Militia:—"We have found that there are limits to the work that a business man can put in, in a military sense. . . . We have been asked the question, What do you think you are for? . . . There must be a naval militia and a naval reserve, and the navy must look to the naval militia as its reserve and as a second line of defense. . . . I am not in favor myself of going on board ships which would go to sea for fighting purposes."

The Naval War College has also marked out the province of the naval militia. "The wars for which we must plan, at least for the next few years, are defensive on our part and to be waged against enemies probably superior to us on the sea. This throws upon us, as a principal rôle, the defense of our coast and the supplementing of our small sea-going navy by a formidable flotilla of small craft, which, when thoroughly organized and drilled, shall dominate our channels, sounds and bays, and make their comfortable or permanent occupation by hostile fleets an

impossibility." (Letter from the president of the War College upon the subject of the naval militia.)

Dismissing then the idea that the naval militia may be depended upon to supply the navy with deep-sea sailors, and granting that its true field is the line of inner defense, the problem of systematic instruction is greatly simplified. Discipline cannot be taught by traveling lecturers; efficient organizers are born, not made. These small beginnings must not be overlooked in the vague longing to tackle some "tremendous and well-nigh impossible task." To produce a well-drilled boat's crew does not need a knowledge of "international law," and if instead of wrestling with "fleet evolutions," "battle tactics" and "naval strategy," attention is given to such primary subjects as handling cutters under oars and sail, heaving the lead, boxing the compass, knotting and splicing, small-arm and boat-gun target practice, etc., the result will be a certain alertness, handiness and self-reliance that will enable the militiaman to be a useful factor when the government calls for his services. For the "habit of the sea," upon which the naval authorities of all nations lay so much stress, should be substituted "the habit of the harbors, rivers and inland waters." Too much credit cannot be given to the naval militia of New York for their work in this direction, and at the same time it must be borne in mind that the initiative came from the State.

Expedients and devices for keeping the men interested in their work make the duties of naval militia officers very onerous. In this the navy cannot be of any material aid; it is a local issue. The plan of having an annual meeting of naval militia officers from the several States, where they can discuss matters of interest to them, bids fair to give excellent results. When the States can agree among themselves as to what they consider their most crying needs, it will be time for the navy to pass judgment. They still seem to be far apart on such questions as uniform, organization, and federal relations, but are practically unanimous as to what their relations to the State should be. The navy can only suggest; it has no authority in the premises. Encouragement always comes from an expression of good-will and sympathy. This has been freely given, and while a process of coercion might in some cases be beneficial, it would surely result in the formation of a Society for the Prevention of Cruelty to the Naval Militia.

The War College has indicated the general lines on which the naval militia ought to expand. The initiative must come from the several States, and the commander that can keep his men on these lines will render the best service to the general government; at the same time, however, he must satisfy his own particular State that his work is also in their interests, and he must be able to so direct the efforts of his men that serious work takes the guise of a diversion. That there are such commanders, experience has already proved. There is no royal road to the naval profession, and the naval militia must be content with its minor phases so long as the commercial spirit of the age forbids, on economical grounds, any large number of our citizens giving a great amount of time to what Captain Mahan calls *preparedness* for war. The enrolling, under

national auspices, of a true naval *reserve* made up from the seafaring classes should be the next step in the organization of a volunteer naval force, but this can hardly be accomplished until legislative stimulation revives our deep-sea merchant shipping.

Lieut. A. P. Niblack, U. S. N.—Mr. Dohrman has been practically the pioneer of the naval militia movement in the Middle West. To his energy and interest the present organization in Ohio is largely due. It is through such patriotic citizens that we can hope to make our readiness for war bear some trifling proportion to our confidence as a nation in our invincibility. The narrow spirit present in all military organizations has given way in our small navy to a cordial recognition of the possibilities of the naval militia. If they have done nothing else, the members of the naval militia organizations have helped us in Congress and with the people. But they have done something else. They have helped stir up the navy itself to a large and broader conception of its own possibilities. That admirable organization, the Naval War College, has been the first to seize upon and utilize the naval militia as an auxiliary to its great work in the preparation for the national defense. As to what shall be the direction the general training of the naval militia shall take that should no longer be an open question. There is danger of making it too diffuse. As the Hon. Wm. McAdoo has often said, "There are so many fields of usefulness for the naval militia in case of war that the difficulty would not be to find work for them, but to select among the many that in which they could serve the country best."

Being State organizations, local laws often limit the field of expansion of the naval militia, but the Navy Department has in the past endeavored to study local conditions in helping the naval militia, but has avoided direct suggestion. As a matter of fact, they want and appreciate direct suggestions.

The present administration is not likely to prove wanting in "directive force," and as the naval militia has arrived at a point where it needs it just now, the movement in general will likely receive a new impulse. Mr. Dohrman's suggestions merit careful consideration in any definite scheme. The navy, the Naval Institute and the naval militia all owe him much for his valuable services.

(*Discussion continued on page 357.*)

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

THE COMPOSITION AND ARRANGEMENT OF SHIPS' BATTERIES.*

By P. R. Alger, Professor of Mathematics, U. S. Navy.

One of the most interesting and important ordnance questions to-day is the determination of the character and disposition of battery most advantageous for the various classes of ships of war.

In the matter of gun construction, progress for some years has been only in the perfecting of details. The breech-loading rifle, built up of forged steel parts, or wire-wrapped, is not likely to be superseded by any other weapon. Improvements in quality of materials may enable us to make guns lighter, and new methods of construction may enable us to make them cheaper, but no radical changes are likely to be made, and it is the perfecting of such details as the firing mechanism and sights that now principally occupies the attention of the ordnance officer.

Gun mountings, too, have been improved to the point where but little further advance seems possible. The balanced gun mount, with hydraulic recoil check and spring return, leaves little to be desired.

As far as ammunition is concerned, great progress has been made in increasing the efficiency of projectiles and fuses, and further progress is being made all the time, but this progress consists in the improvement of what we have, not in the invention of new things. The introduction of the so-called smokeless powders was, indeed, a radical change, putting at the service of artillery the most powerful explosives known, but another similar step in advance can only result from the discovery of an entirely different type of explosive from any now known to chemists.

* Lecture delivered before the Naval War College.

The very fact that all civilized nations use practically the same guns, mounts, projectiles, powder, etc., is a sufficient guarantee that our ordnance material is constructed upon principles of sound reason.

When, however, we consider the composition and disposition of ships' batteries, we find not only the greatest divergence in the practice of different nations, but radically different views adopted in the various designs of each particular navy. It would appear beyond doubt that for every special type of war-ship one particular battery is best suited, and that a little study of the uses to which a given type is adapted, and of the purpose for which the type was developed, would result in at least tolerable unanimity of opinion as to the most efficient armament for that type. The trouble has been that this matter has received of late years too little attention, and its determination has been too much in the hands of people whose interests are enlisted in the development of other features of ship design. The reputation of a ship designer and the profit of a shipbuilder are not affected by her greater or less efficiency as a fighting machine to the same extent as they are by her greater or less speed. The faster a ship, the more widely advertised to the world are her designer and builder; the greater the percentage of displacement allotted to hull and machinery and fittings, the larger the margin of profit on the contract. The wide-spread craze for fast unarmored ships was, in my opinion, born of the personal interests of shipbuilders, and has lived, and even flourished, largely because the military branch of naval service has been excluded from its proper predominating place in the councils which determine the general features of ships of war.

Let it once be recognized that the object of a man-of-war is to win battles, and that battles are won by fighting, not by running, and more regard will be paid to the selection and arrangement of weapons, and the less will offensive power be sacrificed to speed. I have never been able to see what material advantage the commanding officer of a ship would derive from her possession of greater speed than an adversary, nor am I inclined to believe that the commander-in-chief of a fleet will be able to use to any great advantage the high speed of his vessels in an action. Of course, speed is useful as a means of escaping or forcing an engagement, and as giving the power of rapid concentration or

of striking suddenly at a distant object; but when the moment of actual fighting arrives, superiority of speed will weigh as nothing in comparison with superior armament. In the consideration of this subject, moreover, one point has generally been overlooked, and that is, that in many, if not all, modern fast cruisers there is not berthing space for a crew sufficient in numbers to maintain both speed and rate of fire at their highest during an engagement. If sufficient engineer force is employed to keep steaming power at the top notch, the fire of the guns will inevitably slacken at the first serious casualty or from the fatigue of the first few moments of action, relief crews being wanting. The popular idea seems to be that the battle may be won by simply rushing about at tremendous speed, but I think any sensible man would prefer slowing down to slackening his fire.

In the days when sea fighting was the frequent occupation of the naval officer, ships were designed for fighting purposes and everything else gave way to the guns, for experience had taught the lesson that they were what won the battles; too frequently in the recent past a ship's armament has been considered rather in the light of an accessory, to be determined at the convenience of the designer after other requirements have been met. But the experience of the past should be our present guide, and if interpreted with common sense, will lead us to sound and reliable conclusions. The test of war is *not* necessary to decide the relative value of different designs of modern war-ships. If we refuse to be led blindly by authority and rely upon the dictates of common sense in determining the general features of our designs, we cannot go far astray.

The criterion by which *every* war-ship can be rightly judged is the answer to the question, "To what specific use will this ship be put in war time, and is she well adapted to that use?"

The apparent economy resulting from building vessels essentially adapted to the peace duties of a navy is out of all proportion to the depreciation in value of such material in time of war, for which a navy essentially exists, and true ultimate economy consists in building for war purposes only.

Now while there are certain subordinate purposes for which ships of war are needed, I conceive that their principal and fundamental object is to fight other ships of war. Moreover, any given class of ships will naturally be employed in the same general way in our own and in a hostile navy.

Consequently, for whatever specific end a ship is built, it is essential that she shall be so armed as to be able to meet on equal terms a similar ship of equal size. In other words, a certain percentage of the displacement of every ship, the amount depending on her type, should be allotted to her battery, and the character of that battery should be such as to be most effective against an opposing vessel of the same type.

When, for example, we consider the uses to which unarmored cruisers would be put in war time, we find that they can be summed up under four heads: 1. To destroy the enemy's commerce and supply-ships; 2. to convoy and protect our own commerce and supply-ships; 3. to act as adjuncts to the battle-ships, keeping touch with the enemy, giving information as to his movements, and engaging his lighter vessels as opportunity offers; 4. to assist in blockading the enemy's ports.

But in each of these employments they must come in contact with similar ships of the enemy's fleet; if we employ cruisers to attack the enemy's merchant marine, he will employ cruisers to convoy and protect them, and *vice versa*. If he can afford to convoy with battle-ships or to obstruct a trade route with armored cruisers, we must likewise attack and defend commerce with armored ships. On the whole, I do not see how a better rule can be laid down than that every war-ship should be designed for the specific purpose of meeting and whipping any hostile ship of the same class and size.

Of course, a logical deduction from this rule is that the type of ship should be determined by her displacement. Every ship above a certain size should be partially armored, and every ship of a still larger size should be a battle-ship, and this conclusion I personally accept as correct, although it is contrary to universal practice.

Exclusive of torpedo vessels, I would have only three classes of war-ships—unarmored cruisers of moderate displacement, battle-ships of the greatest displacement allowable, and armored cruisers between the other two. Then, as it used to be in the old days, the fighting force would be proportional to the displacement, and none of our ships would have to ignominiously flee from an enemy of equal size. If we build ships to fight, it would certainly seem reasonable to require their cost to be a measure of their fighting value; and I believe that war vessels should be built

for this purpose primarily, not for running after mail steamers or running away from an enemy. Let us then, in the light of the foregoing rule, consider what composition and arrangement of battery is best suited to the various types of ship.

But to do this we must first formulate a method of measuring the relative efficiencies of batteries. What are the factors whose product is a true measure of the value of a given arrangement of guns on any ship when used against an opposing vessel of given characteristics? The value of any one gun is proportional to, 1st, its projectile weight; 2nd, its rate of fire; 3rd, its arc of train; 4th, the area of the opposing ship against which it is effective; and 5th, the importance of the parts of the opposing ship against which it is effective, and their position. In reality, the "weight of projectile" should enter into the formula to a slightly higher power than unity, and in not so using it we are underestimating the value of caliber. This, because the chances of hitting with the big shell are greater than with the small one. The accuracy of modern guns is practically the same for all calibers, and so is the muzzle velocity, but the large projectile loses velocity more slowly, and consequently has a flatter trajectory than the small one. However, to say that the value of a gun is proportional to the weight of its projectile, other things being equal, is near enough to the truth for all practical purposes.

In making the value of a gun proportional to its arc of train, again we are not strictly correct. In the very nature of things an enemy will be more often on one side than ahead or astern, and consequently a gun training over the 90° from bow to quarter is much more valuable than the same gun so placed as to only cover the 90° from one bow to the other or from one quarter to the other. It happens, however, that the form of a ship's deck makes it necessary, if a number of guns are carried, to mount most of them in broadside. The only practicable head fire must come from such guns as can be mounted at the extreme forward end of the battery, and the only practicable stern fire must come from guns similarly situated at the after end.

The fact that a ship is eight or ten times as long as she is broad, and that you cannot without great sacrifices have more than two tiers of guns, makes it inevitable that broadside fire should predominate. Consequently, while in assuming all arcs of train of equal extent to be of equal value we commit an error,

this is compensated for by the fact that the guns with the least valuable arcs of train, ahead and astern, are few in number and are therefore of increased value, because if removed they would leave the ship with no offensive power in those directions. In other words, although heavy head or stern fire is less important than heavy broadside fire, still some head and stern fire is very desirable.

As to the 4th and 5th factors—area of enemy against which effective, and importance and position of that area—these are frequently not taken into account, and yet are of almost determining value. Evidently, if your gun cannot penetrate any portion of your enemy it is absolutely valueless, whereas if it be effective against the entire area of the enemy it has the maximum possible value as far as its chance of doing harm is concerned.

Again, if only effective against unimportant parts of the enemy, evidently a gun has small value as compared with one which can pierce her vital parts. Finally, the distribution of the vulnerable parts is of importance. If the area which a gun is effective against is composed of several smaller areas widely separated, that gun is of less value than if it were effective against an equal area all at the center of the enemy, because in the latter case the chance of hitting a vulnerable part is the greater. Consequently, in assigning value to a gun we must use a numerical factor depending entirely upon the character of the opposing target, and measuring not only the area against which the gun is effective, but the importance and distribution of that area.

Having thus decided as to the method of measuring the value of a single gun, the next step is to determine the value of a number of such guns arranged in a given manner. Of course, if each gun trained over exactly the same arc, both as to extent and position, then n guns would have n times the value of one gun. But suppose, to present the problem in concrete form, we have two guns so arranged that both fire over the same 180° from right ahead to right astern on one side, would this arrangement be better or worse than having one gun on each side each with 180° train? In the first case you could bring two guns to bear as long as the enemy was on one side, and would have no offensive power against an enemy on the other side. In the second case you could always bring one gun to bear on an enemy, but never two.

For my own part I should prefer the concentration of fire over a limited arc in a single ship action, and all-around fire at the expense of power in a fleet action; but it seems probable that in the long run the advantages and disadvantages of the two arrangements would about balance. Consequently I conclude that the measure of the value of any given battery may be arrived at by taking for each gun in the battery the product of its weight of projectile, rate of fire, arc of train, and a numerical factor depending on the character of the target, and adding these products together, which may be summed up by saying, the best battery is the one which gives the greatest volume of effective fire over the largest arc. And it is the qualifying word *effective* in this statement which clearly shows how necessary it is to know the character of her probable adversaries before we can properly assign the battery to any given ship. Measured as above, the most efficient battery for use against a battle-ship will be seen to be very inefficient against an unarmored cruiser, and *vice versa.*

Beginning then with the unarmored cruiser class, let us see what is the most effective battery which such a ship can carry. First, as to caliber, since the weight of the projectile is proportional to that of the gun, and since rapidity of fire increases with decrease in size, it is evident that the smaller the caliber the greater the weight of the projectiles fired in a given time by guns of a given aggregate weight. In other words, 100 tons of 6-pdr. guns will fire several times the weight of projectiles per minute that 100 tons of 5-inch guns will, which would lead us to the adoption for the batteries of unarmored ships of the smallest rapid-fire gun which is effective against similar ships at fighting ranges, were it not for the fact that neither space enough nor crew enough are available for the number of very small guns which can be carried on the weight allotted for the battery of the average unarmored ship. The 14-pdr. is about the smallest gun which can be considered as effective against an unarmored ship at 2000 yards range, and if the entire ordnance weights of the Chicago, for example, were given up to 14-pdr. guns and ammunition, she would carry about 120 of these guns, and the weight of metal thrown per minute by such a battery would greatly exceed that thrown by an equal weight of larger guns. But it would be impossible to find emplacements for so many guns or to carry the crew for their proper handling. Conse-

quently we are forced to go to a higher caliber, and practically we find that maximum effect is given by a battery of the largest guns to which the rapid-fire principle can be applied. This I take to be the 5-inch caliber, the fixed ammunition of which, weighing 95 pounds, is about as much as one man can handle readily at sea. I would have, then, the batteries of all unarmored ships composed exclusively of 5-inch rapid-fire guns, except where the small displacement limited the number of guns too much, in which case the 4-inch gun should be used. Against an unarmored ship such a battery will give the maximum volume of effective fire.

The next question is, what is the best arrangement of such a battery, and it is evident at once that if a considerable number of guns are to be carried they must be in broadside. Of course the mounting of spar deck guns on the center line has the same advantages on unarmored as on armored ships, but it is seldom practicable to do this with small guns—only in the extreme bow and stern of the ordinary cruiser can a 5-inch gun be so mounted as to fire on both sides. If but a few guns are to be carried, they can be put in separate compartments and widely separated; but this, in my opinion, is undesirable. Not only is control of the battery rendered very difficult, but the number of casualties will be increased, owing to the multiplication of bulkheads. But above all, the arrangement of the guns in broadside on one or more decks, clear fore and aft as much as possible, is absolutely necessary in order to carry enough guns to give the great volume of fire which is so desirable.

The best possible defensive position as well as the best possible offensive position for an unarmored ship is with the enemy off the broadside, and the whole aim and object of the commanding officer of such a vessel in action should be to keep in that position. The chance of being hit is then the least, the effect of a shell entering and exploding is the least, and the maximum number of guns are brought to bear.

As an example of what may be done on a moderate displacement, let us take the Chicago and compare her present battery with one which might replace it. The Chicago is now armed with four 8-inch, eight 6-inch and two 5-inch guns, besides a secondary battery. These can be replaced without increase of weight by 30 5-inch rapid-fire guns with 50 rounds of ammuni-

tion each, or if we do away with the secondary battery we can have 70 rounds each. It would seem to many unwise to have no secondary battery guns on a ship, but with a very large number of rapid-fire guns bearing on all points I am inclined to think that a better defense against torpedo-boat attack can be obtained by the use of canister from the larger rapid-fire guns than by the shell-fire of the smaller calibers. Can any one doubt on which side the advantage would lie in an action between two Chicagos, one with her present battery, the other with 30 5-inch rapid-fire guns?

It may very properly be said that 70 rounds per gun is an inadequate supply of ammunition, but this is due to the large percentage of the Chicago's displacement used for machinery and boilers. The new weights for the Chicago are 182 tons less than the old ones, and she is to have three knots more speed. Moreover, a saving of about 40 tons more is to be effected by removing her spars and rigging. Of the total saving, 87 tons is to be used for an additional coal supply, but the remaining 135 tons would give 100 rounds more per gun if allotted to ordnance. With a battery of 30 5-inch rapid-fire guns, and with 170 rounds of ammunition per gun, the new Chicago would seem likely to be at least a fair match for any unarmored ship afloat.

In criticising the batteries of unarmored ships it is only fair to remark that the rapid-fire gun of large caliber is a development of the past few years, and smokeless powder, which will so greatly add to the effectiveness of rapid fire, is but now coming into service use.

The possible batteries of the heavy armored ships, which constitute the real fighting force of navies, on the other hand, are much the same to-day as they were when armored ships began to be built and the turret was invented. For twenty-five years the usual and only reasonable arrangement has been two or more heavy guns in turrets and a number of smaller guns wherever places could be found for them. The progress in ship construction, ordnance and armor has done nothing more than make the ships larger, the guns heavier, and the armor thicker and more resisting. There is, however, a vast difference in efficiency between batteries of equal weight and the same general character but differently arranged. If one gun can be so placed as to do the work of two guns otherwise arranged, the gain which results is very great, for the weight saved can be used in increas-

ing the protection of the remaining guns, while the decreased number of gun positions lessens the area of target, and consequently the chance of being hit. Now, a gun on the middle line of a ship is exactly equivalent to two guns, one on each side, provided it can fire across the deck. Again, a pair of guns in a single turret can be given the same armored protection on two-thirds the weight required if they are mounted singly. It follows almost of necessity that the heavy guns of an armored ship should be mounted in pairs in turrets on the middle line. Certain other arrangements having fictitious claims to superiority have been advocated and are embodied in many foreign ships as well as in some of our own. Let us examine these arrangements.

Assuming the main battery to consist of four turret guns of very large caliber, there are four feasible arrangements:

1. Four single-gun turrets, two on each side.

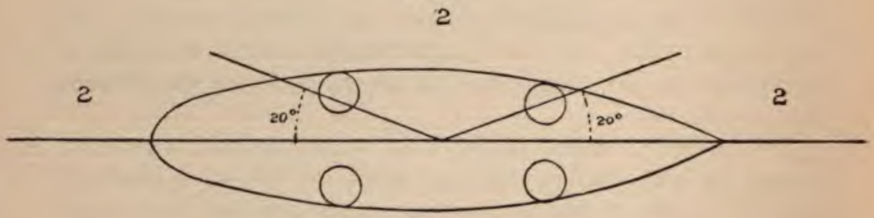
2. Four single-gun turrets, one on each side, one forward and one aft on middle line.

3. Two double-gun turrets, one on each side.

4. Two double-gun turrets, on the middle line.

The following diagrams show the relative weights of fire and arcs of train with these arrangements.

No. 1.



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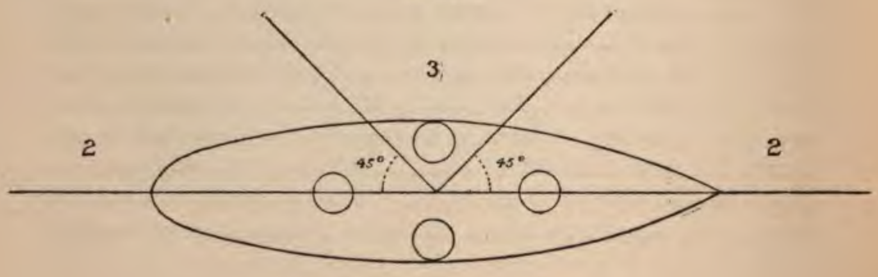

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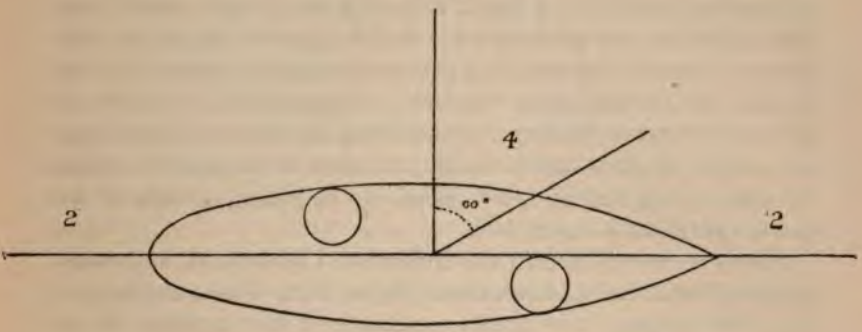

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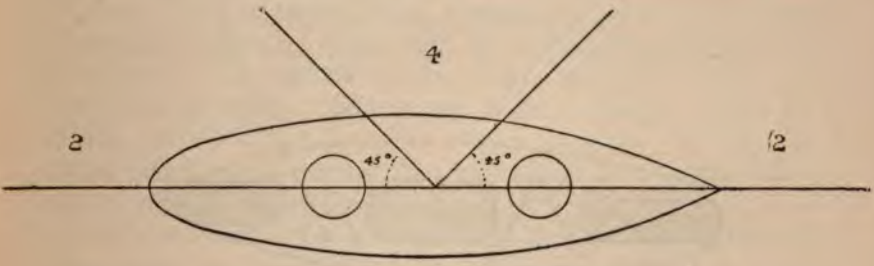
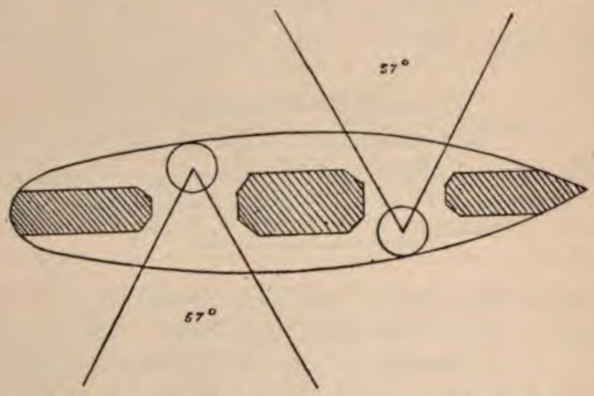


The first arrangement is partially exemplified only in some old French ships, the Richelieu and Ocean. The fact that but two guns can be brought to bear in any direction utterly condemns this arrangement, which is probably the worst possible one.

Plan No. 2 is a marked example of the sacrifice of real to fictitious advantages. The plausibility of the argument in favor of this arrangement is shown by the number of ships whose design embodies it—the Marceau, Hoche, Magenta, Pelayo and others. It is often claimed that with this design three guns bear on every point, but an examination of the diagram shows this not to be the case. It is doubtful if the side guns can fire directly ahead and astern, but granting that they do, even then but *two* guns bear over arcs of 45° on each bow and quarter, and only three on the remaining 180.° As compared with plan 4, this arrangement, with equal armor protection, costs 50 per cent. more in weight and gives only three-fourths the weight of fire on the

broadside and equal weight ahead and astern. Moreover, it gives almost double the target area of plan 3—four turrets with their barbettes and ammunition tubes as against two of but little greater diameter—as well as a grouping specially likely to be hit. Finally this arrangement renders it impracticable to carry an efficient secondary battery. If the side guns are to be fired ahead and astern no guns can be safely mounted in the space between the end turrets, and of course none can be placed outside of this space, except on a lower deck.

Plan 3 is exemplified in the Inflexible, Colossus, Agamemnon, Andrea Doria, Italia, Aquidaban, Maine, Ting-Yuen, and numerous other ships. It is another example of the sacrifice of real advantages to fictitious ones existing only on paper. This arrangement of a turret on each side has numerous variations,



the fore and aft distance between the turrets being more or less in different designs. Even in the largest ship it is impracticable to have the two turrets abreast each other, and in some ships they are widely separated, one being almost on the bow and the other on the opposite quarter. The Maine is a good example of the latter variation, and I will now try to show that in no case can this arrangement equal in efficiency that shown on plan 4, although the further apart the turrets are the better.

As will be seen, the Maine's guns have, on paper, 180° arc of fire on one side and 57° on the other. Even accepting this as practicable, the result is that only over an arc of 57° on each side can all four guns be used, whereas in plan 4 they all bear over 90° on each side. But in reality the forward guns of the Maine cannot

fire, safely, closer than 5° to ahead and 15° from astern, so that there is an actual dead angle of about 20° ahead and 20° astern. Moreover, the 57° angle shown on the plans must be greatly reduced unless we wish to destroy the superstructure on and in which the secondary battery guns are mounted. Manifestly, it should be the object in handling such a ship in action to bring all four main battery guns to bear on the enemy, but to do this the enemy must be kept within an arc of bearing of about 45° on one side or the other, whereas by simply moving the turrets inboard to the central line and concentrating the secondary battery between the turrets we at once increase to 90° on each side the arc within which all four guns bear on an opponent.

When the turrets are close together and on opposite sides of the ship, as in the Italia, the dead angles ahead and astern are increased. For example, in the Rugiero di Lauria the forward turret guns cannot fire nearer than 20° to the line of the keel forward and not so near aft, giving a dead angle of at least 45° ahead and 45° astern, while the arc of fire across the deck is no greater than in the design with turrets far apart. In fact, the further apart the turrets are the more nearly plan 3 approaches plan 4, and, consequently, the better it is.

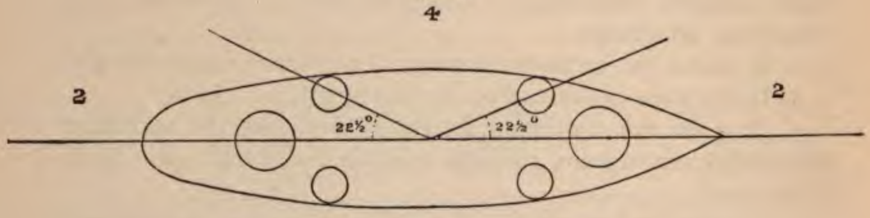
The arrangement shown on plan 4 is the one adopted for our own battle-ships, the Indiana class, the Iowa, and the new battle-ships, and it is also embodied in the Camperdown, Trafalgar and other English battle-ships. This plan has the following overwhelming advantages:

1. It allows the greatest thickness of armor for a fixed weight.
2. It offers the poorest target to an enemy.
3. It gives the maximum weight of fire over the maximum practicable arc of train, and also over the arc of train most likely to be used.
4. It gives the best opportunity for mounting a large secondary battery.
5. It affords opportunity for safe stowage of a reasonable number of boats.
6. No interference of fire results from the use of any gun over its whole arc of train.

Concluding, then, that two turrets on the middle line afford the best disposition for the four heavy guns, the next question is what shall the remainder of the battery be? If it were practicable to carry another pair of the largest caliber guns in a third

turret on the middle line, it would be a most powerful arrangement, but several considerations prevent this. In the first place, the 900 or 1000 tons weight required is not available; in the second place, there would be great difficulties in the matter of supports and ammunition supply, on account of the necessary internal arrangements of the ship; and, finally, there would be no space left for secondary battery guns. But another consideration would lead us to condemn this arrangement; a very large part of all modern armored ships is protected by thin armor, four to six inches in thickness, which is invulnerable to rapid-fire guns but no match for the 8-inch caliber. If we carry only rapid-fire guns and 12-inch or 13-inch guns, we cannot get that *volume* of effective fire which is so desirable; the only projectiles which can penetrate the vital parts of the enemy will be delivered at no greater rate than one a minute, whereas by carrying 8-inch guns we can treble the number of effective shots. Concluding, then, that the four large caliber guns should be supplemented by some of medium caliber in addition to the rapid-fire guns, we have to determine their number and disposition. The Indiana class and the Iowa carry each eight 8-inch guns in four turrets arranged as in plan 1, but the arguments already advanced condemn this arrangement, and we have to choose between four turrets as in plan 2, or only two turrets as in plan 3.

No. 1.



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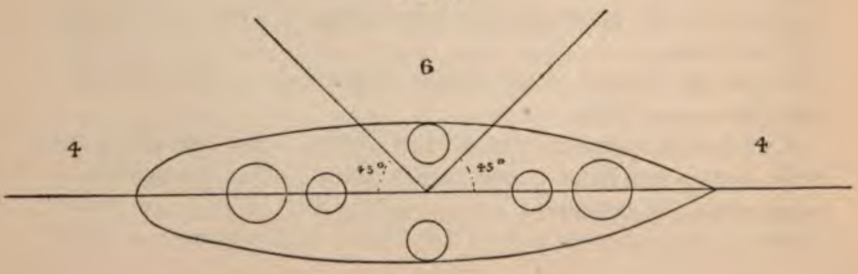

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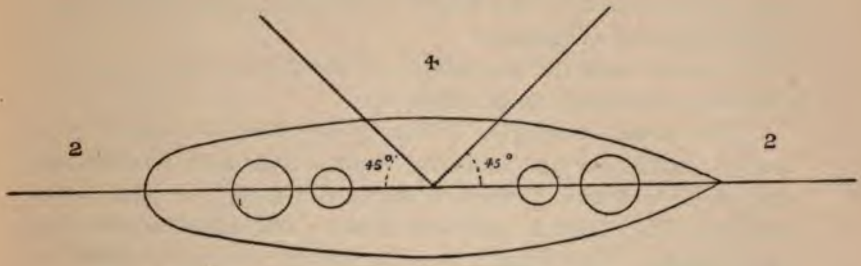


Comparing the three arrangements, it is at once apparent that at an expense in weight of four gun positions we get from the first plan the fire of four guns over 270° and of two guns over 90°; from the second plan on the same weight we get the fire of six guns over 180° and four over 180°, while from the third plan, one-half the weight, we get the fire of four guns over 180° and two over 180°. Where displacement is limited, as it is for our battle-ships, the greatly increased protection possible with the last plan is of itself enough to commend it, but other reasons are even stronger. With the four turret plans no space is left for a battery of small rapid-fire guns, at least four less 5-inch rapid-fire guns can be carried, and no space is available for stowage of boats. Moreover, the multiplication of gun positions increases the difficulty of regulating fire, a necessity with the battle-ship even more than with the cruiser. The gun captain, from his sighting hood on the turret top, can form no reliable estimate of distance, nor is he likely to be able to observe the fall of his shot. Some method of measuring the range and signaling the proper sight-bar setting to each gun position is essential, and the fewer the positions the easier to maintain communications.

One further and most important objection exists both to the second plan and to the third as it is shown, and that is the impossibility of the 8-inch guns firing safely over the 13-inch turrets. Blast plates have been proposed to cover the sighting hoods of the 13-inch turrets, but experiments at the Proving Grounds appear to have shown that they would prove ineffectual. Certainly with both 8-inch and 13-inch guns trained on the bow or quarter, it would fare ill with the people in the 13-inch sighting hoods when the 8-inch guns were fired.

It was to overcome this objection that the double-storied turret was first proposed by the Board of Ordnance, but it has many other important advantages.

Let us see what the advantages of the double-turret plan are, and what objections can be made to it.

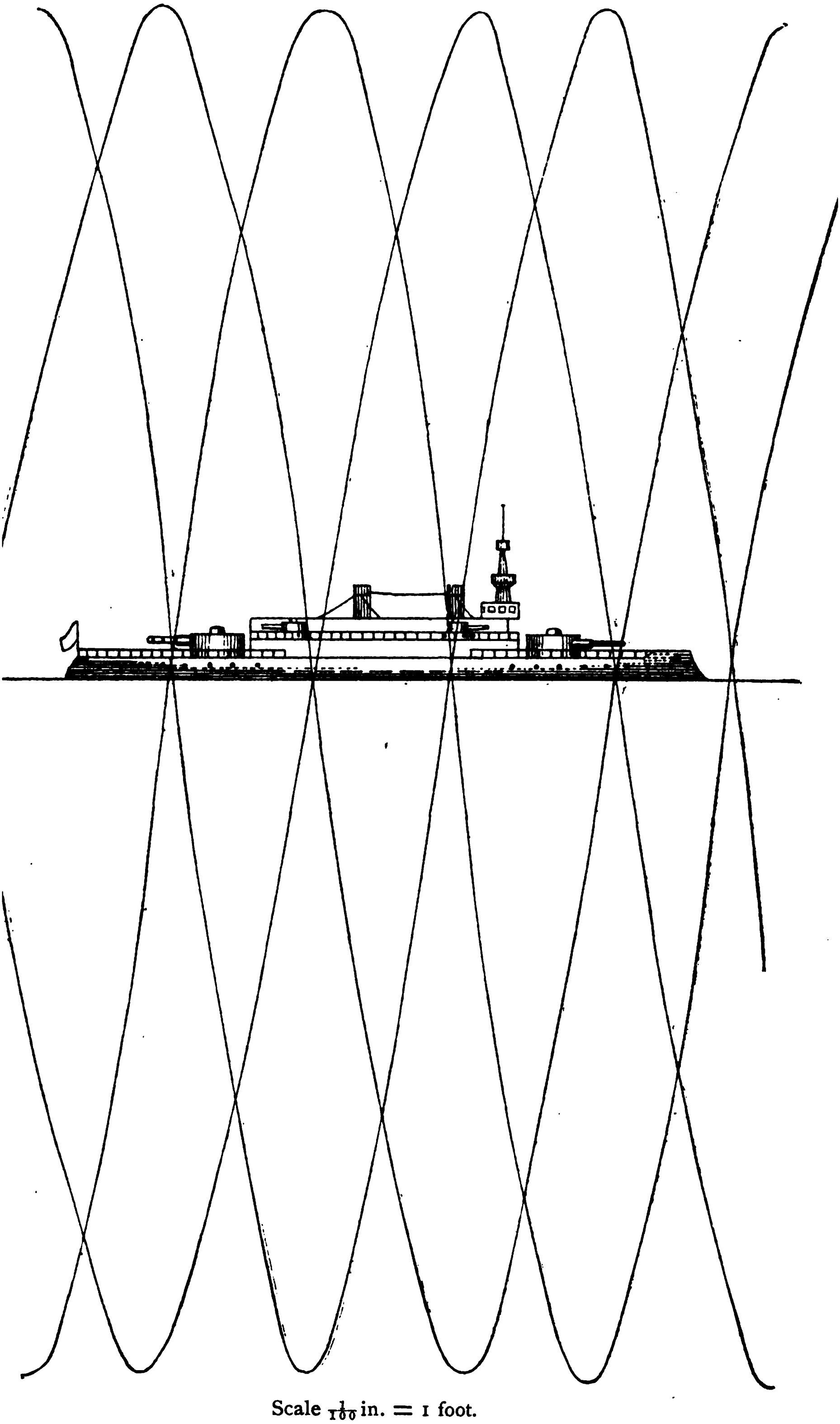
1. The saving of weight. Four 13-inch and four 8-inch guns can be carried on 246 tons less weight than four 12-inch and eight 8-inch, armor thickness being the same; or with equal batteries, four 13-inch and four 8-inch, and equal armor, 160 tons is saved. This weight, or even a small part of it, enables us to greatly increase the armor protection of the 8-inch guns.

2. Smaller target area and better disposition of target. No better target could well be offered than is afforded by the arrangement of two large and four small turrets. With the enemy a little forward or abaft the beam, a nearly continuous target is made by the turrets, and the thin ones are nicely arranged about the center of impact where the greatest number of hits will occur. With two gun positions widely separated, the maximum immunity from hits is attained.

3. Better control of fire. The double turret will be trained by one specially expert man, and better results must be given by this than where there are several turrets each with its own trainer. Moreover, there are but two main gun positions to which range and other directions must be signaled.

4. Vastly better opportunities for placing the secondary battery and for carrying boats. The clear space between the turrets gives room in the superstructure for at least fourteen 5-inch guns, and on the superstructure for as many small rapid-fire guns as desired, as well as for all necessary boats. Moreover, there is absolutely no interference of the fire of any gun by another.

5. Reduction in amount of machinery and mechanism. The training engines, roller paths, rollers, etc., of the 8-inch, the slightest injury to which would put the turret out of action, are done away with, and the training mechanism of the 8-inch guns being the same as for the 13-inch, is protected by 15 inches of armor instead of six or seven inches. Should the training gear of one of the main turrets be disabled with either design, the fighting force of the ship would be almost halved, unless by skillful manœuvring the guns of the disabled turret can be brought to bear; consequently, to do this would be the main effort of the



Scale $\frac{1}{100}$ in. = 1 foot.

The sinuous line indicates the intersection of the line of sight on the plane *of the target-ship* as the firing ship rolls through an angle of only *four degrees, the speed of the target-ship being ten knots.*

commanding officer, and with the double turrets both 13-inch and 8-inch guns would bear at the same time.

The objections urged to the double turret and their answers are as follows:

1. *Concentration of weights.*—This is not as great as in many foreign designs, nor even as great as in the Indiana class.

2. *Difficulty in supplying ammunition.*—This is not great. The 8-inch shell would be stowed in the 13-inch barbette, and, consequently, the men putting ammunition into the hoists would be on different decks and not interfere with each other. In the actual hoisting of the ammunition there is no trouble at all.

3. *Impossibility of training 8-inch and 13-inch guns on different parts of the enemy.*—This is an imaginary difficulty. An examination of the drawings will illustrate this. The intersection of the line of sight with the vertical plane containing the enemy's ship is a curve of rapid motion, and it needs but the recollection of actual experience in aiming guns at sea to convince any one of the absolute impracticability of selecting one portion of a ship as the target. "*Aim at the middle of the target*" should be the almost invariable rule. In that way the maximum number of hits will be obtained. The old experience that "the waist of the ship is a death-trap" illustrates this fact, the greatest number of hits naturally being about the point aimed at; but the theory of probabilities of fire indicates that with the errors common to gun fire at sea, even where the objects to be struck are at the ends of the ship, you will get the most *hits* by aiming at the middle between them.

If concentration of fire is desired, then the double turret renders it possible, all four guns being fired simultaneously by electricity, but in no other way can it be obtained.

But it would be too long to fully discuss this arrangement, and I can only say that the more I have thought of it and discussed it the more firmly I have been convinced of its advantages.

As to the question of the remaining battery of battle-ships, there seems to be no doubt but that it should be made up of rapid-fire guns, and these can only be placed in the superstructure between the main turrets. In the Kearsarge and Kentucky there are to be fourteen 5-inch rapid-fire guns in broadside, and these guns cannot fail to add greatly to the fighting force of the

ships. A very large area of every ship must be unarmored, and while there may be no vital parts so unprotected as to be vulnerable to the 5-inch gun, still the wreckage of the unarmored portions must tend to the demoralization of the crew. Moreover, smokestacks, ventilators, masts and boats are targets whose destruction may be a serious injury, while the gun ports and sighting holes offer possible chances of entry into the armored structures, and the water-line at the ends, as well as the sides above the belt amidships in many ships, can be so cut away as to endanger stability notwithstanding coal and cellulose protection.

As against the virtues of such a battery let us consider those of the new battle-ships which follow the Kearsarge and Kentucky. These ships are to have four 13-inch guns in turrets on the middle line, but in place of the 8-inch and 5-inch they are to have fourteen 6-inch rapid-fire guns, ten mounted in broadside between the 13-inch turrets and four on top of the superstructure also in broadside, and so arranged that one on each side fires right ahead and one right astern. Taking the rates of fire as one round a minute for the 8-inch, two and one-half rounds a minute for the 6-inch, and three rounds a minute for the 5-inch, it will be seen that with the Kearsarge plan the weight of fire per minute is 2050 pounds on the broadside and 500 ahead or astern, while with the later plan it is only 1750 on the broadside and 500 ahead and astern. But the main objection to the second plan is that the volume of effective fire is enormously diminished by the omission of 8-inch guns. The large area covered with thin armor is fairly safe from the 6-inch guns at fighting ranges, whereas the 8-inch projectile at any range, and at even a considerable angle of incidence, will penetrate it. If we measure the value of the two batteries by the rules heretofore laid down. it is evident that the Kearsarge's battery will prove much the more efficient.

We have finally to consider what is the best battery for the armored cruiser class, and first, what is the function of the armored cruiser. I consider her to be simply a ship big enough to be partially armored, but not big enough to carry very heavy guns or very thick armor, and as with all other classes of warship, she should be designed with a view to have at least equal chances in battle with any other ship of equal size. She is a

cruiser of sufficient displacement to be armored, and consequently requiring guns capable of piercing armor. From my point of view, every ship of more than about 4500, and of less than about 9000 tons displacement, should be an armored cruiser. It is folly to build 9000-ton ships which can be knocked out by properly armed ships of half their size.

We have thus far designed but two armored cruisers, the New York and Brooklyn, the first of about 9000 tons, and the last of about 10,000 tons displacement with full bunkers. The batteries of these ships are respectively six 8-inch and twelve 4-inch guns and eight 8-inch and twelve 5-inch guns.

The New York's 8-inch guns are arranged four in two turrets on the middle line and a single gun in each waist. By simply putting the two waist guns in a turret on the middle line, which could be done without changing the arrangement of boilers or machinery, how much more powerful her battery would be! In order to use the 4-inch guns the enemy must be kept not greatly forward or abaft the beam, and in this position, with present design, five 8-inch guns would bear, while by the proposed change all six would bear. In the same way how greatly improved the Brooklyn would be by putting her side 8-inch turrets on the middle line, or if that be impracticable, which I do not believe, by giving her only three turrets, all on the middle line. These would give exactly the same fire on the beam as is now given by four turrets, and the saving of weight could be used to great advantage in increasing the thickness of the turret armor.

As for the rapid-fire guns of an armored cruiser, they should be arranged on a single deck in broadside, and should be as many in number as space will allow.

There is no lack of displacement available if we only dispense with the many worse than useless weights which we now carry. Let all useless bulkheads be removed, all wood sheathing torn off, and we can put a battery of rapid-fire guns on the New York and Brooklyn that will render it unnecessary to answer the frequent and annoying question of visitors to those ships, "But where are your guns?"

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NOTES ON THE YACHT "DEFENDER" AND THE USE OF ALUMINUM IN MARINE CONSTRUCTION.

By Richmond Pearson Hobson, Asst. Naval Constructor, U. S. Navy.

No craft in the annals of yachting centers about itself such features of general interest as the yacht Defender. Perhaps the greatest series of races in these annals is the one that represents in its sphere the great fact of modern times—the greatest fact, it may prove to be, of all time—the rise of the New World, a rise to greatness that has reached, and in some respects has passed the point of successful rivalry with the Old World.

Among the yachts connected with the series of races for the America's cup, Defender is in many respects unique, standing head and shoulders above all the distinguished number.

The last races came at a time of high tide in yachting interest both abroad and in the United States, when rivalry was keenest and the evolution of the racing craft seemed to have reached its maximum. The determination to win back the lost trophy was made years in advance, and one can trace the course of deliberate, scientific, tireless effort to this end, till at last it seemed, with great reason, that invincibility had been reached in Valkyrie III.

It was immediately recognized in America that the defense of the cup could not be left to any yacht yet built; moreover, the time after challenge would be too short to permit experiment. Valkyrie III was the successor to a dynasty that reached its climax of perfection before the challenge was sent; while the American champion might be expected to follow the line of its predecessors,

and might be expected to be the climax of a sequence of representatives, yet there was but one chance of producing the climax.

The sense of danger aroused the American yachtsmen to the necessity of co-operation. Effort combined and centered upon producing a single craft. The order was placed with Herreshoff Bros., of Bristol, R. I., and cost and all other considerations were subordinated to the one object, speed. The yacht built must win.

It was natural, under these conditions, to expect boldness, for the builders, though sure in execution, have been characterized by boldness in design.

The shape this boldness took for realizing a maximum of power was along the line of weight distribution, for lowness of center of gravity, rather than along the line of maximum metacentric radii, or power of form. The advantage of excessive lowering of the center of gravity, instead of the raising of metacenter, becomes apparent, without further explanation, from reference to the fact that power of weight, determining the position of the center of gravity, does not incur, as does power of form, determining the position of the metacenter, the increase of head resistance and frictional resistance that sets in when the vessel heels or is in a seaway.

The method adopted for lowering the center of gravity consisted not only in placing a maximum weight of lead on the deep fin keel, as found also in the Challenger and other yachts, but also in reducing to a minimum the upper weights, the saved weight appearing in the form of additional lead on the keel, being equivalent in effect to a transference of weight downward through a great desistance.

The reduction or economy of weight, particularly of high weights, which thus constituted the characteristic feature of the yacht, places her construction alongside of marine construction in general, and of naval construction in particular, where weight of hull and fittings affects intimately the limit of the military qualities themselves.

This coincidence of purpose alone would make the yacht an interesting study for the naval architect, but the form the purpose took enhances the interest, makes it general and intense, for it adopted a new material—aluminum—which, from its extreme lightness, has been offering great hopes to the naval architect, but which, from its corrosion in salt air and salt water, has

checked, if it has not effectually shattered these hopes. Moreover, the conditions were peculiarly such as to constitute a severe test of the virtues and failings of the new metal.

In view of this similarity of purpose with naval construction, particularly the bearing on torpedo-boat construction, and of the value of the experiment with aluminum, the Navy Department directed an inspection of the yacht and a report on her "method of construction." This report is given in Part I practically as it was made after inspection at Bristol just before the yacht left the builder's hands.

In August last, more than a year afterward, a second inspection was made at New Rochelle, through the courtesy of Oliver C. Iselin, Esq., to determine the conditions of preservation and the conduct of the new material in the face of the deteriorating conditions of service. Since it is on the question of corrosion that the use of aluminum for marine purposes hinges, an effort was made to throw, if possible, some additional light upon the subject, particularly at the present time, when, notwithstanding the advantage it offers, aluminum has been unfavorably passed upon, both abroad and in this country, upon grounds that appear to be incomplete. Samples of corrosion taken from the Defender, also a sample of a corroded aluminum plate, together with a sample of the salt water in which, in a closed vessel, the corrosion took place, the latter furnished by Professor A. H. Sabin, were sent to the chemist at the Navy Yard, New York, with directions for a qualitative and a quantitative analysis, with a view to determining the phenomena of corrosion in the particular case, the attacking agents, the soluble and insoluble products.

The value of an intimate knowledge of the phenomena is evident, serving as it would as a basis for research and experiment to find preventative preparations.

A sequence of heavy pressure in the chemical laboratory has prevented as yet the analyses, and effort to hasten them since the writer's detachment from the New York Navy Yard has been of no avail. Only an incomplete, preliminary analysis of the corrosion from Defender has been reported, an analysis so incomplete as to be of no material value.

It has therefore been decided to give in Part II the result of the study of the subject of the adaptability of aluminum for marine construction, without the original data hoped for on the question of corrosion.

PART I.—THE METHOD OF CONSTRUCTION OF THE YACHT DEFENDER.

1. *Preliminary Description.*

The boat was examined while afloat at anchor. Her general form is indicated in Figs. 1 and 3. Her approximate hull dimensions are as follows: Length over all, 122 feet 3 inches; length on load water line, 90 feet; maximum beam, 23 feet; beam at load water line, 22 feet; draught, extreme, 19 feet.

The idea that gives the distinguishing feature to this advance type, as will be seen below, is the realization of extreme sail

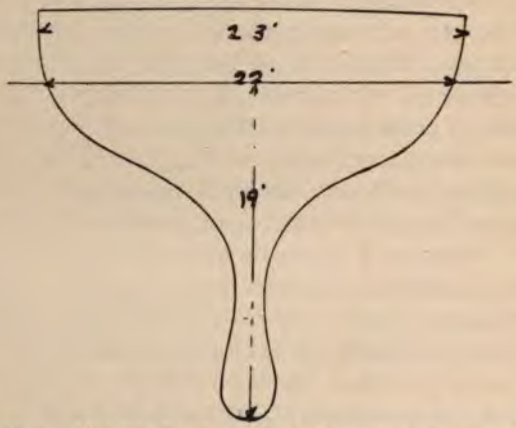


FIG. 1.—Midship Section in Outline—approximate only.

carrying power from a great metacentric height, initial and under inclination, realized from the disposition of weights. Though realizing a high position of the metacenter from an elevated position of the center of buoyancy and long metacentric radius, the extreme is reached in the low position of the center of gravity.

The great metacentric height and consequent sail-carrying power is derived more from the element of weight than from the elements of form.

The method adopted in realizing the low position of the center of gravity is that of reduction in weight of hull and fittings and the addition of weight to the keel, weight being taken from the upper portions and added to the lowest point.

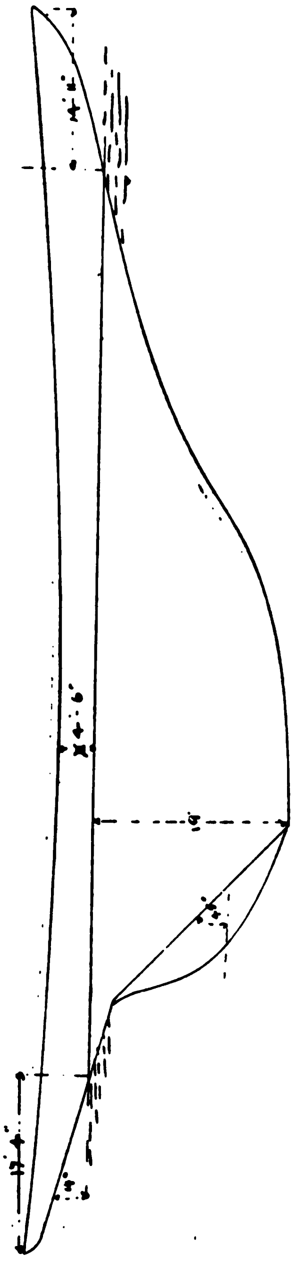


FIG. 2.—Longitudinal Profile in Outline.

The method of realizing a reduction of high weights is the use of light materials, of light scantlings, with a light method of construction and fastenings.

The reduction of frictional resistance and of liability to deterioration are sought in the use of bronze, manganese bronze, for water-washed portions.

The features of the distinguishing methods thus identify the construction, in the objects sought, with the construction of vessels of war, particularly torpedo vessels and torpedo-boats.

2. *The Method of Construction.*

Referring to the sketch of the midship section, Fig. 3, the construction is as follows:

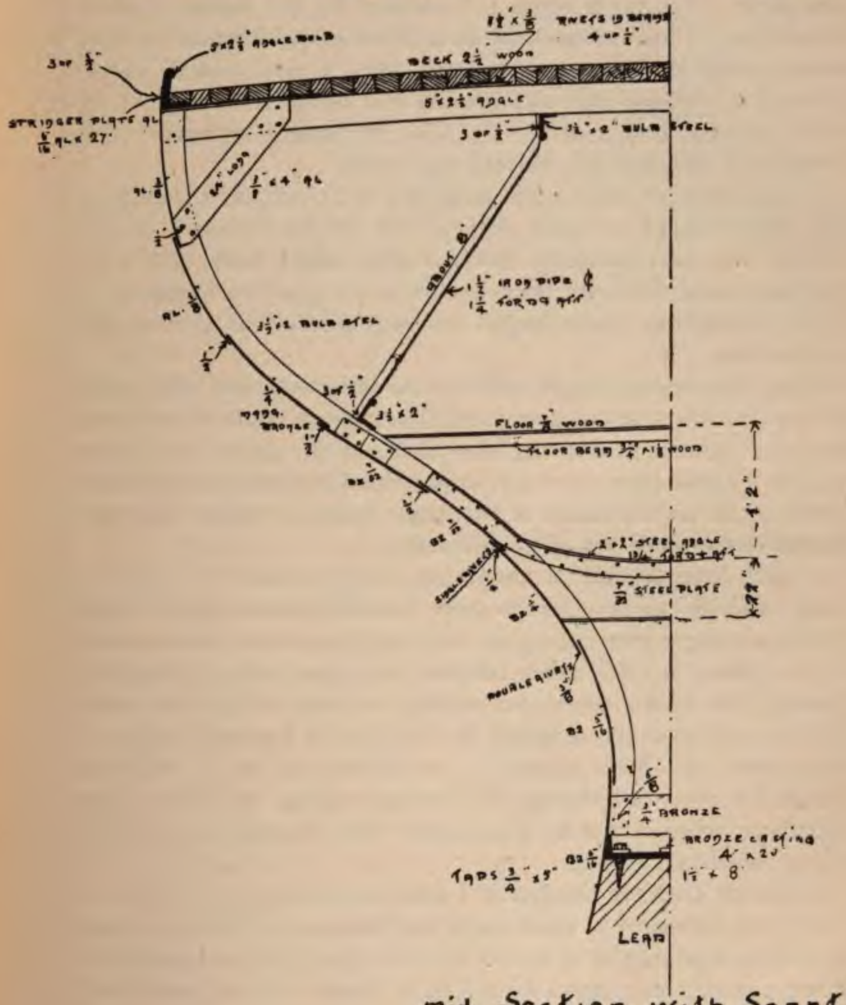
1. THE SKELETON.—A steel angle, 4" x 4", closed to the angles of the water lines, from ¼" to ⅜" thick, forms the stem and binds the ends of the shell plating, with double riveting, rivets of bronze for the bronze plating, diameter ⅝", and of aluminum for the aluminum plating, diameter ½".

A bronze casting, 4" deep by 20" wide, of the form indicated in sketch, forms the *keel*. On its under side is attached the lead, shaped to the form indicated, secured by bronze tap bolts 8" long by 1¼" diameter. The bronze *shell plating* extends to cover the lead, reducing the frictional resistance, and giving additional support, securing to the lead by bronze taps 5" long by ¾" diameter.

The *frames* are steel angle bulbs made in two parts between the keel and top sides, strapped and riveted as indicated, spaced 20" throughout, an angle being substituted for the bulb at the forward extremity, frame No. 1. They stop at the keel, which is spanned by floor plates of ¼" bronze plating, 12" high, secured to the frame on each side by five rivets of ⅝" diameter. Alternate frames have in addition deepened *floor plates*, of $\frac{7}{32}$" steel, extending, as shown, to the angles uniting the frames at about one-third their height from the keel. These angles are steel, 2" x 2" amidship, and 1¾" x 1¾" forward and aft. The frame angle bulbs are 3½" x 2" amidship. The following is their scantlings throughout, beginning forward: Frame No. 1 is an angle, as stated above; from frame No. 2 to frame No. 9 the angle bulbs are 2½" x 1½"; No. 10 is 2¾" x 1¾"; from No. 11 to No. 24 they are 3" x 1¾"; from No. 25 to No. 44 they are 3½" x 2"; from No. 45 to No. 58 they are 3" x 1¾"; from No. 58 to stern they are

$2\frac{1}{2}'' \times 1\frac{1}{2}''$. The dimensions for the bulb of the frame angle bulbs, $3\frac{1}{2}'' \times 2''$, are $\frac{7}{8}'' \times \frac{9}{16}''$.

About four and a half feet above the steel angles that bind the



Mid. Section with Scantlings

FIG. 3.

two sides of the frames are *wooden beams*, $3\frac{1}{4}'' \times 1\frac{1}{8}''$, secured to the frames, adding stiffness and forming support for the platform or lower deck.

The *beams* of the upper or main deck are aluminum angle bulbs, 5" x 2", spaced 40", fitted to only alternate frames, the frames without beams ending without fittings under the deck stringers. The beam arms are secured to the frames against which they sit back to back by three rivets of ½" diameter and by a single strip of aluminum plating 24" long, 4" wide and ⅜" thick, forming a triangle with the frames and beam arm, secured by three rivets at each end of ½". The two beams between which the mast is strapped are of steel, 4¼" x 2¼".

A *bilge stringer*, steel angle bulb, 3½" x 2", extends throughout the entire length on each side, at the height indicated in the sketch. A corresponding inverted steel angle bulb, 3½" x 2", extends under the main deck beams in the position indicated in sketch along the whole length on each side about 4' from the central line.

The bilge stringer angle bulb and the inverted angle bulb under beams on each side are connected by 14 *struts* made of iron piping, 1½" amidships and 1¼" forward and aft, spaced five frame spaces. These pipes have forgings welded in their ends and flattened to lie on the backs of the angle bulbs, to which they are secured by three rivets of ½" diameter.

A *deck stringer plate* of aluminum, varying from 28" to 24" in width and $\frac{5}{16}$" thick, extends over the beams from end to end. On this stringer plate, along its outer edge, extends an aluminum angle bulb, 5" x 2½", which receives the upper edge of the shell plating and forms the upper ending of the hull at the sides. The deck beams are strapped in addition by diagonal plates of aluminum, ⅜" thick, varying in width from 5" aft to 7½" forward, the four converging on the mast being 10" wide. The length of these strapping plates and their disposition are indicated in sketch, Fig. 4.

Thus the skeleton consists of a steel angle stem, a bronze keel, with lead underneath, steel angle bulb frames, with floor plates of alternating heights, of bronze at the bottom and steel above the bronze, with steel angles binding the frames on the two sides, wooden deck beams for the lower deck, and aluminum angle bulbs for the main deck beams, fitted only to alternate frames, steel angle bulb bilge stringers, one on each side, inverted steel angle bulbs on under side of main deck beams, one on each side, two rows of inclined struts between bilge stringers and inverted

angle bulbs under main deck beams, one row on each side, spaced every five frame spaces, aluminum deck stringers and angle bulb at sides of main deck, and diagonal deck strapping fore and aft.

2. THE COVERINGS.—The *shell plating* is on the raised and sunken system, with liners behind frames under outside plating, secured to frames by a single row of rivets of ½" diameter. All butt straps are double riveted.

Strake No. 1, covering the lead and overlapping the keel and lower part of frames, as indicated in sketch, Fig. 3, is an outer strake of manganese bronze $\frac{5}{16}$" thick amidship, secured to the lead by bronze taps ¾" diameter and 5" long. The lap with strake No. 2 is secured by two rows of rivets of bronze ⅝" diameter.

Strake No. 2 is an inner strake of $\frac{5}{16}$" manganese bronze. The lap with strake No. 3 is double riveted, ⅝" bronze rivets.

Strake No. 3 is an outer strake of ¼" manganese bronze. The lap with strake No. 4 is single riveted, ½" bronze rivets.

Strake No. 4 is an inner strake of $\frac{7}{32}$" manganese bronze. The lap with strake No. 5 is single riveted, ½" bronze rivets.

Strake No. 5 is an outer strake of $\frac{7}{32}$" manganese bronze. The lap with strake No. 6 is single riveted, ½" bronze rivets.

Strake No. 6 is an inner strake of ¼" manganese bronze. The lap with strake No. 7 is single riveted, ½" bronze rivets. The load water line falls on this strake near its upper edge, between the water line and the aluminum plate above.

Strake No. 7 is an outer strake of ⅜" aluminum. The lap with strake No. 8 is single riveted, ½" aluminum rivets.

Strake No. 8 is an inner strake of ⅜" aluminum. This strake is the highest. The upper edge secures to the back of the angle bulb, forming the top line. The lower ends of the strips securing beam arms fall on the lower part of this strake.

The *decks* are of wood, 2¼" thick for the main deck and ⅞" thick for the lower deck. Liners are fitted over the beams of the main deck between the strapping plates. The deck planks are secured to each other by horizontal nails in addition to being secured to the beams. Around the mast a steel tie plate, 5′ 3″ x

3′ 4″ x ⅜″, secures the ends of the strapping plates and the four beams in the vicinity.

Thus the coverings consist of manganese bronze for the water-washed portions of shell plating, and aluminum for the top sides, with wood for the decks, and steel for special plates.

3. Fittings.—The *socket for stepping* mast is made of steel angle bulb, 5″ x 2½″, bent to the form of a circle with the ends welded and strapped. The flange, which is on the exterior, sits on a foundation plate of steel. The stepping is stiffened by a partial vertical keel or keelson and by special floor plates on the frames adjacent, with angles 4″ x 4″ on one side and 2″ x 2″ on the other, with vertical angles 2″ x 2″.

The pin rails are of steel piping. The rigging on each side is secured to steel eye bolts attached to 5 chain plates, about 4½″ wide and ⅝″ thick, extending down to the lower deck, riveted to the shell plating.

The jibboom is guided by two main straps of bronze about a foot long with flanges at the ends, and by an additional narrow strap of simple bronze plating.

The fid is of aluminum, in the form of a yoke which receives tie rods which are of one piece bent around the stem and, passing through the ends of the yoke, are set up by nuts, which permit of an adjustable strain on the single jumper or martingale of steel wire, secured to the stem a short distance above the water line. There is no lateral support of the jibboom.

The standing rigging and topping lifts are of light steel wire. Blocks are of Oregon pine or spruce with straps and sheaves of aluminum. Cleats are of hard cast bronze. Eye bolts are of steel. The spars are of Oregon pine and spruce. The internal fittings are of light wood with minimum thickness. Partitions and partial bulkheads are of canvas, held by a light wood framing. The water-closet fittings are of aluminum, with small pump of aluminum. The bunks for the crew are of ½″ gas tube frames, 6′ x 23″, covered with canvas, hinged lengthwise to the side and folding or dropping down. They are three tiers deep, with about 20″ vertically between the bunks. They are secured in the horizontal position by straps from the reverse angle bulbs under the main deck beams.

Thus the fittings are of steel, bronze, aluminum or wood, according to the requirements.

3. CONCLUSIONS.—The method of construction as above described presents three prominent features, namely:—

1. Simplicity and directness of construction.
2. The use of new materials and their combination with steel.
3. Lightness of scantlings.

The complex nature of the forces to be resisted, the combination of pronounced twisting and a heavy thrust of mast with the usual forces, would lead to the expectation of complexity, whereas examination shows an entire absence of redundant parts, and even of parts found in usual construction.

The examination of the parts in view of the forces to be resisted shows a singular directness of purpose for each part or piece that enters the construction. These characteristics, simplicity and directness, are so evident from the sketch of the midship section that they need not be pointed out in detail. Notice should be taken, however, of the use of angle bulbs instead of simple angles or combinations of angles. The sectional moment of inertia being greater for the angle bulb, there is a gain in stiffness, or a saving in weight for the same stiffness. Notice should be taken also of the simplicity of fastenings, the economy of rivets.

Special attention should be given to the system of struts, which, though exceedingly light, give to the transverse sections a girder-like nature hitherto unattempted afloat. Special attention should be called also to the disposition for insuring continuity of resistance in the main deck, to the longitudinal angle bulbs under the deck beams, and the combination of angle bulbs and wide deck stringers at the sides, but especially to the diagonal strapping which opposes itself directly to the twisting forces referred to above, note being taken also of the fastenings of deck planks to each other.

It may be added that the characteristics in question appear in full relief when the boat is conceived inclined under the great localized forces; when the parts are conceived distributing these forces and transmitting them to the resisting forces without, the structure will be seen to present remarkable stiffness of form, remarkable resistance to deformation, combined with the simplicity of structure described above.

In sum, the boat is an architectural departure and is an interesting study for all architects. For the marine architect the

study is of practical value, for the departure is along the line of his constant effort to realize a maximum of resistance to complex forces with the minimum of weight.

The realization of this main object, however, is not confined alone to the *disposition* of the material, but extends also, with even more marked characteristics, to the *selection*. The lightest strong metal known to architecture is used wherever characteristics other than weight do not prevent. The shell plating of the top sides, the main deck beams and strips securing them to the frames, the deck stringers and top side angle bulb, the deck strapping plates, and various fittings, enumerated above, are of aluminum. The builders claim a gain or saving of ten tons over steel construction as used in the yacht Colonia of nearly similar build. The transfer of this weight from the top sides to the keel, through a vertical height of about 21′, causes the distinguishing characteristic referred to at the beginning, that of a lowness of center of gravity which places this boat apart from all other products of marine construction.

This use of aluminum presents particular interest from the effort it represents to realize not only a gain in weight, as yet moderate in quantity when compared for simple strength with steel, but also the more pronounced advantage afforded by a more efficient disposition of metal, a section of greater inertia, and consequent greater stiffness, than can be realized with the smaller quantity of the heavier and stronger metal.

In addition, in view of service and deterioration which sets in from the surface and which may be looked upon as penetrating readily a certain distance and then ceasing, the thicker plate of the lighter metal offers decided advantage over the thinner plate of the stronger metal, assuming equality of strength when first built. These features are important ones in maritime construction, particularly in naval construction.

The last feature is of particular importance in torpedo-boat construction, which requires the use of plates of extreme thinness.

The advantage of taking weight from lower portions and putting it on the keel is less pronounced than for the case of the upper portions. Further, a special bronze alloy, stronger than steel, though heavier than aluminum, offers, when polished, pronounced advantage over all painted or varnished surfaces, according to the experience of the builders, in smoothness of surface.

The water-washed portions of the shell plating are of manganese bronze, from which results of ultimate strength are realized about 12 per cent. in excess of the results of steel used for the same purpose. In view of the additional fact that the under water parts are for the most part on the compression side of the hogging girder, and will consequently be less called upon for resistance within tensile elasticity, and of the fact that bronze offers advantages in maintenance of smoothness, according to the builders, and decided advantages in resistance to deterioration, this feature is one of particular interest in naval construction, particularly in the case of torpedo-boat construction, where deterioration is most injurious.

In sum, the construction of the boat seeks to realize the advantages offered by two materials that may be considered new, and presents for study all the interest that attaches to the experiment of these materials in the new field of hull construction.

But in seeking to realize the advantages of the new materials the builders have not lost sight of the advantages still offered by the old. For the frames and floor plates and for special fittings like the tie plates around the mast and the chain plates and, in general, the parts where the advantages offered by aluminum and bronze are less in evidence, and where special strength without special stiffness is desired, use is made of steel, with evident advantage. It should be noted that the lower parts of the floor plates, 12" in height, which are liable to corroding effects of bilge water, are made of bronze.

In sum, the boat seeks to realize the advantages offered by all three of the materials, aluminum, special bronze, and steel.

Though aluminum boats have been built abroad, and though bronze has been previously used by the builders in conjunction with steel on the Vigilant, the combination of aluminum, bronze and steel has never been attempted. In material, as in architecture, the boat stands apart. But, further, simplicity and directness of construction and new materials and new combinations of materials are not the only characteristics of this remarkable boat.

An examination of the scantlings as described above, and as seen on the sketch of midship section, shows throughout a lightness that is remarkable when it is remembered that the boat is essentially a structural experiment on untrodden ground. This lightness of scantlings is most marked in the region of the mast.

It is true that here are found the maximum dimensions of pieces, the heaviest scantlings of outside plating, that the two beams between which the mast passes are of steel instead of aluminum, that the deck strapping plates are increased in width, and that a special steel tie plates binds up the four beams, and the ends of the four strapping plates, but even with these special dispositions the provisions do not appear commensurate with the local strains, particularly on the weather side, that the structure will undergo by reason of the narrow spread of the stays, introducing an enormous thrust of the mast and crushing force between the sides due to the enormous spread of sail and the great height of the center of pressure. Notwithstanding the special provisions enumerated, it appears not improbable that a heavy wind, particularly if applied suddenly, will cause the structures in the region of the mast to spring, if not to give way, it being assumed that the mast is sufficiently robust not to give way beforehand. In view of the experimental nature of the boat, this feature of lightness, particularly in the region of the mast, is second in its striking nature only to the features described above, and offers an interesting field for the calculation of the strains to which the materials are liable to be subjected. This feature has not been included in the present examination of the " method of construction," but a summary investigation leads to the conclusion that the scantlings are such as to bid fair to afford a conclusive, if not crucial, test of the strength of the new materials.

But the test of strength is not the only test in store for the new materials: the test of endurance will also be conclusive. The materials are in a combination that will produce serious effects of galvanic action, if such action is liable to take place under the conditions of service. The aluminum and bronze are not only in contact with each other, but are both in contact with steel, and this contact is most intimate in the case of rivets passing through two or more different materials, as is the case of rivets between frames and shell plating. It is to be noted that methods have been used to obviate as far as possible the liability to this action, such, for instance, as the avoidance of the use of aluminum below the water, the use of bronze for the bottom of the floor plates where liable to be in contact with bilge water. The conditions of service will test the efficiency of these methods.

The test will extend to the use of bronze for the water-washed

surfaces, to the extent of the advantage it offers for the resistance to deterioration and to fouling, and, if possible, it should be made to extend to finding the extent of the advantages it offers in frictional resistance, the increased smoothness compared with painted and varnished surfaces.

Thus, in sum, the Defender, while presenting a remarkable study of simplicity of construction and efficiency of distribution of materials, embodies two new materials in such light scantlings as to offer a test of their strength, and in such combination and disposition as to offer a severe test of their qualities of endurance, of resistance to deteriorating influences.

The objects throughout, that of realizing a maximum of strength with a minimum of weight, particularly in the upper parts, of realizing a minimum of skin resistance, are identical with the objects in naval design, more particularly in torpedo-boat design; while the methods adopted, the use of three materials, two of which are new, in a combination which seeks to realize the special advantages of each, and the means resorted to to prevent the bad effects liable to the combination, are all steps across the border at which torpedo-boat construction has arrived into the fields beyond.

This interesting production has sought to realize the extreme of sailing advantages along the road that torpedo-boat construction must follow in coming developments of hull construction, and the conditions are peculiarly favorable for its cutting away many of the obstacles and indicating what changes in direction are best for entering the new ground.

To realize the advantages of the experiment, investigation should extend to cover the behavior of the new materials under the tests of strength, during stress and after repeated stresses, and under the tests of endurance and resistance to deterioration.

PART II.—THE USE OF ALUMINUM IN MARINE CONSTRUCTION.

A new material enters the realm of structural usage by creating new fields or else by outstripping the occupants of old fields.

Broadly speaking, the field of marine construction is now occupied by steel, wood, and the alloys of copper. Aluminum must, in consequence, wrest from these older materials the foothold and territory it is to occupy.

A part of this field, associated principally with the motive power, is shut off from aluminum by an impassable barrier of temperature. A fraction of the temperature at which bronze and steel remain unmodified will overthrow the physical properties of aluminum. Roughly speaking, aluminum is barred from temperatures where human life cannot exist. Not far beyond the boiling point of water it loses half its virtues of resistance, and above 400° F. should not be subjected to strain.

In addition, by reason of its softness, aluminum is debarred use as armor, which constitutes an important section of naval construction. Moreover, as will be seen below, its inability to extinguish sudden and violent dynamic forces excludes usage for armor supports and fastenings.

Of the remaining fields not thus cut off, principally hull construction and hull fittings, the vast bulk is occupied uncontestedly by steel. Wood and bronze (the term bronze being used broadly to signify the alloys of copper) have only special provinces, wood finding its principal use where stiffness, not strength, is required, and where the service does not require a hardness of surface, but facility of working; and bronze finding its principal use where complexity of form requires special properties for casting, or where special corroding agents are to be resisted, or where a wearing surface is desired to save the usure of steel.

Even the special properties of bronze and wood may be considered as possessed, to a greater or less degree, by steel. Aluminum then will be made to measure properties with steel, the special properties of wood and bronze being considered only incidentally where they appear in the comparison with steel.

The factors whose product or resultant determines or measures the adaptability of a material for structural purposes are strength, weight and cost, strength and cost being used in their broad sense. The measure of adaptability for strength is the approximation to a maximum, and for cost and weight it is the approximation to a minimum. In marine construction the problem of design in general is to realize within a fairly wide range of cost a given or required strength with a minimum of weight.

The underlying object in general is to realize a maximum military efficiency for each unit of weight.

In the industries, however, and in general for land structures, the purpose of design is to realize a given or required strength

with a minimum of cost, a minimum of weight in general accompanying a minimum of cost. The underlying object in general is to realize, within a wide range of weight, a maximum return for each unit of cost or capital invested.

For the present purpose, therefore, the comparison of aluminum and steel will be for strength and weight first, then for cost.

The question of endurance, or length of life, which will be seen to be of capital importance, is essentially one of cost, though intimately associated with strength, since the rate or rapidity of dissipation of strength determines the length of life.

The figures used in the comparisons of aluminum are the latest ones of the Pittsburg Reduction Company, for their best 5 to 10 per cent. alloys. These figures are probably a little high for the general status of aluminum at the present moment, particularly when the comparisons of simple strength are made with mild steel, mild steel being used throughout, as it is the most regular, and best illustrates, as will be seen, the great contrast of the two metals in their resistance to dynamic forces; but they have been retained in view of the present rapid state of progress in the production and manufacture of aluminum, a state corresponding to the stage of steel about ten years ago, when still on a steep rise far away from the proximity of the maximum in the curve of progress.

A.—Comparison for Simple Resistance.

1. *In tension.*

(*a*) *Ultimate tensile* strength:—Steel, 60,000 lbs. per sq. in. Aluminum, 40,000 lbs. per sq. in. Ratio, 1 to 1.5 or 2 to 3.

Cross sections for *equal ultimate* tensile strength, see Figs. 5 and 7.

Weights:—Weight of one cubic inch of steel, 0.283 lb.; of aluminum, 0.094 lb. Ratio, 1 to 3.

Weights for *equal ultimate* tensile strength, aluminum 1, steel 2.

(*b*) *Elastic strength in tension*:—Steel, 30,000 lbs. per sq. in. Aluminum, 28,000 lbs. per sq. in. Ratio, 14 to 15, or 1 to 1.07.

Cross section for *equal* elastic strength in tension, see Figs. 6 and 8.

Weights:—For *equal* elastic strengths in tension, aluminum 0.356, steel 1, or 1 to 2.8.

2. *In compression.*

(*a*) *Ultimate strength of compression*:—Steel, 60,000; aluminum, 34,000. Ratio, 1 to 1.76.

Weights:—For *equal ultimate* strengths of compression, aluminum 1, steel 1.7.

(*b*) *Elastic strength in compression*:—Steel, 30,000 lbs. per sq. in. Aluminum, 26,000 lbs. per sq. in. Ratio, 1 to 1.15.

Weights:—For *equal elastic* strengths of compression, aluminum 1, steel 2.6.

3. *Ultimate strength in shear*:—Steel, 45,000 lbs. per sq. in. Aluminum, 28,000 lbs. per sq. in. Ratio, 1 to 1.6.

Weights:—For *equal ultimate* strengths of shear, aluminum 1, steel 1.875.

Double riveted joints:—Steel, 45,000 lbs. per sq. in. Aluminum, 24,000 lbs. per sq. in. Ratio, 1 to 1.875.

Summing up, for simple resistance, the comparison gives the following results:

1. For *ultimate tensile strength*, mild steel is half again as strong as the best aluminum alloy, but at the same time it is three times as heavy; in consequence, the same strength can be furnished by aluminum with half the weight that steel would require, or, with the same weight, aluminum would furnish double the strength.

2. For *elastic strength in tension*, aluminum is fourteen-fifteenths as strong as steel, and can supply the same elastic strength with but 0.36 of the weight required by steel; or, with the same weight, aluminum would furnish 2.8 times the strength.

3. For *ultimate strength of compression*, steel is 1.76 times as strong as aluminum, but to furnish the same strength would be 1.7 times as heavy.

4. For *elastic strength of compression*, aluminum is thirteen-fifteenths as strong as steel, and to furnish the same strength steel would be 2.6 times as heavy.

5. For *ultimate strength in shear*, steel is 1.6 times as strong as aluminum, and would be 1.875 times as heavy. When the shear is that of a riveted joint, where the riveting is double, steel is 1.875 times as strong. The lower performance of the double riveted joint would indicate for aluminum a less perfect co-operation among the rivets. As will be seen later, this is no doubt due to the very small elongation in the aluminum, which is no doubt the case for shear as it is for tension, causing the shearing more in detail, the rivets most strained giving way before there is

sufficient elongation to permit the full concurrence of the rivets less strained.

6. In sum, for *simple resistance*, from the standpoint of *strength* and *weight* alone, aluminum has pronounced advantages over steel, advantages that are nearly *double* for ultimate resistance, and nearly *treble* for elastic resistance.

This result emphasizes a striking feature of aluminum, namely, the very large proportion of its total strength that is elastic. While this proportion for steel is *half*, for aluminum it is seven-tenths.

The consequences of this remarkable property will be seen below in the comparison of resistance to dynamic forces; it will suffice for the moment to refer simply to the fact that the vast bulk of structural resistance must be elastic.

B.—Comparison for Compound Resistance.

For the present purpose, resistance to torsion need not be considered; moreover, there is lack of reliable data for the resistance of aluminum to torsion, and comparison would require an assumption of strength based upon the resistance to shearing. The comparison will therefore be limited to bending.

Recalling the formula, the bending moment,

$$M=\frac{sI}{h}, \tag{1}$$

s being the stress per unit area of the fiber most strained, I the moment of inertia of the cross section, and h the distance of the fiber most strained from the neutral axis which passes through the center of gravity of the cross section.

Where the material has a different resistance for tension and compression, it is evident that with symmetrical cross sections, the fiber under the stress of the lesser kind of resistance will give way first, and would impose the limit to the bending moment.

It is also evident that the resistance of a given cross section for such a material is a maximum when the area is so distributed that the extreme fibers of tension and compression are distant from the neutral axis in the direct ratio of their respective resistances. When so distributed, the bending moment, $M=(s_c+s_t)\frac{I}{h}$, where s_c is the maximum resistance to compression, s_t the maximum resistance to tension, and h the entire depth of the beam.

In the cases of aluminum for ultimate resistance, the resistance to tension being 40,000 lbs. per sq. in., and the resistance to compression 34,000 lbs. per sq. in., the symmetrical section would have its limit imposed by the fiber under compression, and the ratio of the resistance of such a section to the resistance of a section designed to give a maximum resistance, if the moment of inertia is the same, is $\dfrac{34000}{\dfrac{40000+34000}{2}} = \dfrac{34}{37}$. For elastic resistance the ratio is $\dfrac{26000}{\dfrac{28000+26000}{2}} = \dfrac{26}{27}$.

With steel, however, the two resistances are the same and the symmetrical section realizes the maximum resistance.

The ratio $\frac{37}{34} = 1.09$ and $\frac{27}{26} = 1.04$ would represent the advantage to be derived from the best design for the aluminum section provided the moment of inertia did not change.

It is evident, however, that the transference of metal from the side of tension to the side of compression will result in placing this metal nearer the neutral axis and in consequence will reduce the moment of inertia. The two ratios, therefore, while remaining appreciably greater than unity, will be less than those indicated, 1.09 and 1.04, according to the form of the section.

Bearing in mind this small but appreciable discrimination against aluminum, it will suffice, for the sake of simplicity, to compare only symmetrical sections.

1. *Comparison of usual sections designed for resistance other than bending.*

(*a*) The case of *square cross sections* designed for *tension* or *compression.*

The ratio of bending moments, from equation (1), is

$$\frac{M'}{M} = \frac{s'}{s}\,\frac{I'}{I}\,\frac{h}{h'}, \tag{2}$$

the letters with the affixes denoting aluminum.

If the side of the aluminum section is n times the side of the steel section, $h' = nh$, or $\frac{h}{h'} = \frac{1}{n}$.

The *areas* of the cross sections being in the ratio $\frac{h'^2}{h^2} = n^2$ and

the radii of gyration squared in the ratio $\frac{h'^2}{h^2} = n^2$, the moments of inertia are in the ratio $\frac{h'^4}{h^4} = n^4$ and $\frac{I'}{I} = n^4$,

$$\therefore \quad \frac{M'}{M} = \frac{s'}{s} \times n^4 \times \frac{1}{n} = \frac{s'}{s} n^3. \tag{3}$$

Take first the case illustrated in Fig. 5, of (1) *section designed for equal ultimate tensile strength*, designating by S and S' the two ultimate tensile strengths.

$$h'^2 S' = h^2 S \text{ or } \frac{h'^2}{h^2} = \frac{S}{S'} \text{ or } n^2 = \frac{S}{S'} \text{ and } n = \sqrt{\frac{S}{S'}}.$$

Substituting in equation (3), $\frac{M'}{M} = \frac{s'}{s} \cdot \left(\frac{S}{S'}\right)^{\frac{3}{2}}$.

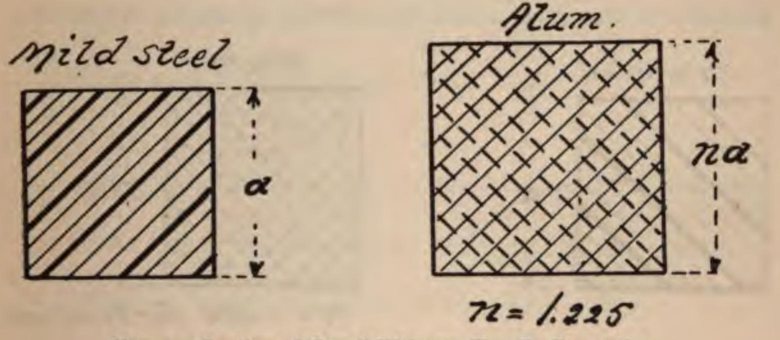


FIG. 5.—Section of Equal Ultimate Tensile Strengths.

Suppose first that the cross sections are worked to their limit of resistance to bending. It is the extreme compressed fibers of the aluminum sections which will break first when $s' = 34{,}000$ lbs. per sq. in. The fibers of the steel section resist equally for tension and compression, both attaining 60,000 lbs. per sq. in., so that $\frac{s'}{s} = \frac{34000}{60000}$. The two ultimate tensile strengths S and S' being 60,000 and 40,000 respectively,

$$\frac{S}{S'} = \frac{60000}{40000} \text{ and } \frac{M'}{M} = \frac{34000}{60000} \times \left(\frac{60000}{40000}\right)^{\frac{3}{2}} = 1.04.$$

Suppose next that the cross sections are worked only to the elastic limit of the most strained fibers.

The limit for the aluminum cross section is again imposed by the fibers of compression where $s' = 26000$.

For the steel section the limit being the same for both fibers,

$s = 30{,}000 \qquad \frac{s'}{s} = \frac{26000}{30000}.$

S and S' being the same as before,

$$\frac{M'}{M} = \frac{26000}{30000} \times \left(\frac{60000}{40000}\right)^{\frac{3}{2}} = 1.6.$$

It does not suffice in general to know simply the *amount of resistance* to bending. It is also necessary to know the effect of the bending moment, the amount of deformation or deflection produced. It is therefore necessary to calculate the resistance to deformation, to know the stiffness. The measure of stiffness is the amount of bending or the deflection produced by a given force. The amount of deflection, $f = \frac{K}{E.I}$, where E is the modulus of elasticity, and I the moment of inertia of the cross

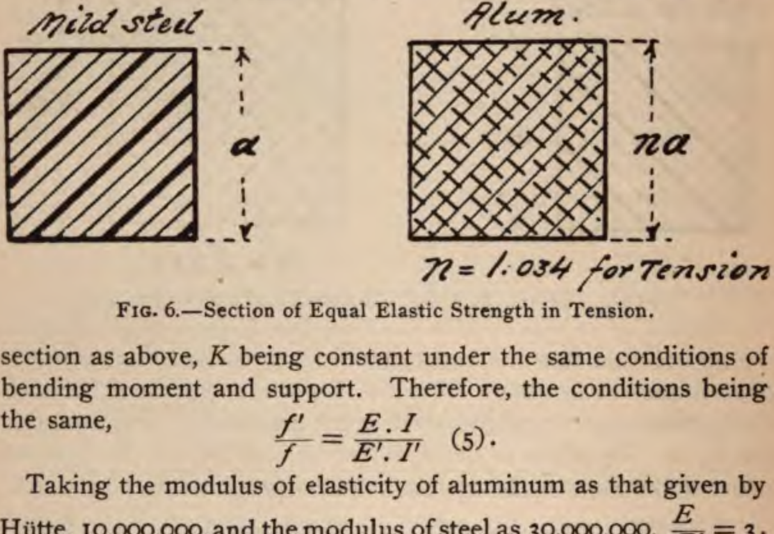


FIG. 6.—Section of Equal Elastic Strength in Tension.

section as above, K being constant under the same conditions of bending moment and support. Therefore, the conditions being the same,

$$\frac{f'}{f} = \frac{E.I}{E'.I'} \quad (5).$$

Taking the modulus of elasticity of aluminum as that given by Hütte, 10,000,000, and the modulus of steel as 30,000,000, $\frac{E}{E'} = 3$. As seen above, for the case in question, $\frac{I}{I'} = \frac{1}{n^4}$, where $n = 1.225$, $\frac{I}{I'} = \frac{1}{2.25}$. Substituting in equation (5), $\frac{f'}{f} = \frac{3}{2.25} = \frac{1}{0.75}$. Thus, for square cross sections giving equal ultimate strengths in tension, the deflection produced by the same force under similar conditions of bending is greater in the case of the aluminum section. The square steel bar is one-third the stiffer.

(2). *Sections designed for equal elastic strength in tension,* illustrated in Fig. 6.

By a similar process of reasoning,

$$\frac{M'}{M} = \frac{34000}{60000} \times \left(\frac{30000}{28000}\right)^{\frac{3}{2}} = .627\,,$$

when worked to the ultimate limit.

$$\frac{M'}{M} = \frac{26000}{30000} \times \left(\frac{30000}{28000}\right)^{\frac{3}{2}} = .959\,,$$

when worked to the elastic limit.

$$\frac{f'}{f} = \frac{3}{1.143} = \frac{1}{.381}.$$

(3). *Sections designed for equal ultimate strength of compression.*

When worked to the ultimate limit, $\dfrac{M'}{M} = 1.328$

When worked to the elastic limit, $\dfrac{M'}{M} = 2.031$

$$\frac{f'}{f} = \frac{1}{1.032}.$$

(4). *Sections designed for equal elastic strength of compression.*

When worked to the ultimate limit, $\dfrac{M'}{M} = .703$

When worked to the elastic limit, $\dfrac{M'}{M} = 1.073$

$$\frac{f'}{f} = \frac{1}{.441}.$$

(5). *Sections of equal weight.*

When worked to the ultimate limit, $\dfrac{M'}{M} = 2.94$

When worked to the elastic limit, $\dfrac{M'}{M} = 4.50$

$$\frac{f'}{f} = \frac{1}{3}.$$

b. The case of rectangular cross sections designed for tension plates of a given width.

Refer to Figs. 7 and 8.

The areas of the cross sections are bh' and bh respectively, b being the *width*; the radii of gyration squared are in the ratio of $\frac{h'^2}{h^2}$.

Therefore, the moments of inertia are in the ratio of $\frac{h'}{h} \times \frac{h'^2}{h}$ $= \frac{h'^3}{h^2}$, and the bending moments are in the ratio

$$\frac{M'}{M} = \frac{s'}{s} \times \frac{h'^3}{h^3} \times \frac{h}{h'} = \frac{s'}{s} \times \frac{h'^2}{h^2} = \frac{s'}{s} \times n^2. \qquad (4)$$

(1). *Sections designed for equal ultimate strength.* Fig. 7.

FIG. 7.—Plates of the same length and breadth and of Equal Tensile Strength.

When worked to the ultimate limit, $\frac{M'}{M} = 1.275$

When worked to the elastic limit, $\frac{M'}{M} = 1.94$

$$\frac{f'}{f} = \frac{1}{1.125}.$$

(2). *Sections designed for equal elastic strength.* Fig. 8.

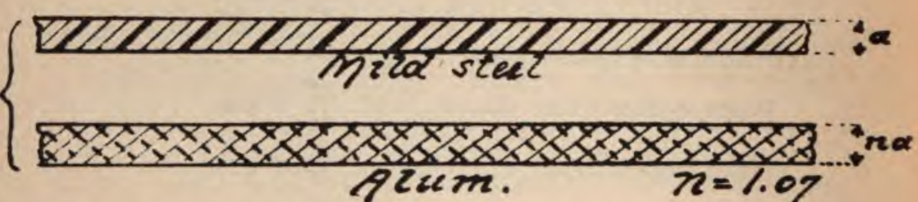


FIG. 8.—Plates of the same length and breadth and of Equal Elastic Strength.

When worked to the ultimate limit, $\frac{M'}{M} = .648$

When worked to the elastic limit, $\frac{M'}{M} = .99$

$$\frac{f'}{f} = \frac{1}{.408}.$$

(3). *Sections designed for equal weight.*

When worked to the ultimate limit, $\frac{M'}{M} = 5.1$

When worked to the elastic limit, $\frac{M'}{M} = 7.8$

$$\frac{f'}{f} = \frac{1}{9}.$$

2. *Comparison of sections designed for resistance to bending.*

a. Shapes having equal weight.

(1). I *Beams.* Fig. 9.

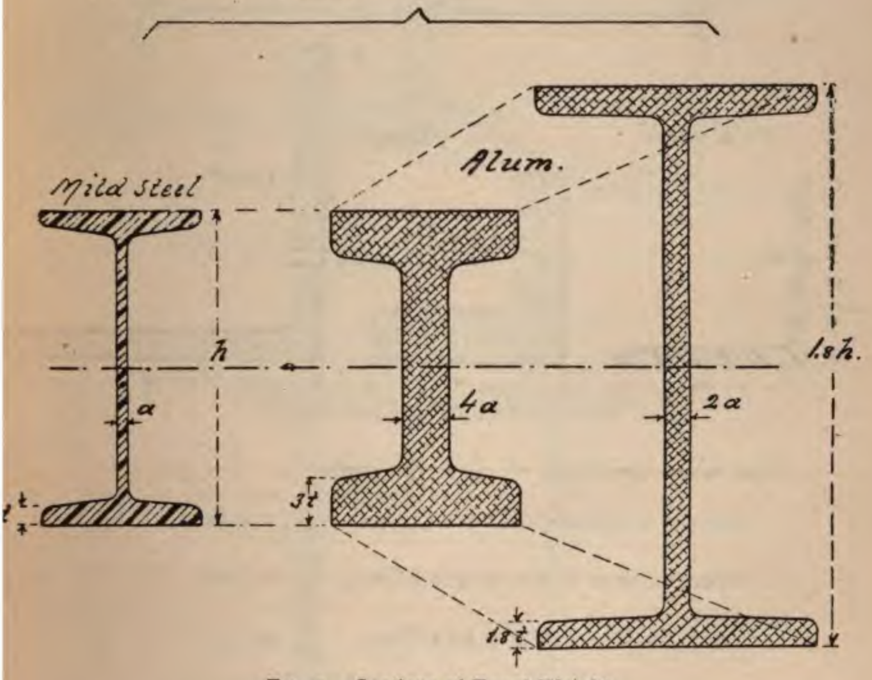


FIG. 9.—Sections of Equal Weight.

First, when the *depth* of I beams is limited, being the *same* for *both sections.*

Ratio of moments of inertia, $\frac{I'}{I} = 2.36$

When worked to the ultimate limit, $\frac{M'}{M} = 1.43$

When worked to the elastic limit, $\frac{M'}{M} = 2.05$

$$\frac{f'}{f} = \frac{1}{.786}.$$

Next when the depth is not limited, and the sections have proportioned dimensions.

Ratio of moments of inertia, $\frac{I'}{I} = 9.25$

When worked to the ultimate limit, $\frac{M'}{M} = 2.91$

When worked to the elastic limit, $\frac{M'}{M} = 4.45$

$$\frac{f'}{f} = \frac{1}{3.08}.$$

(2). Angle bars, ∠. Fig. 10.

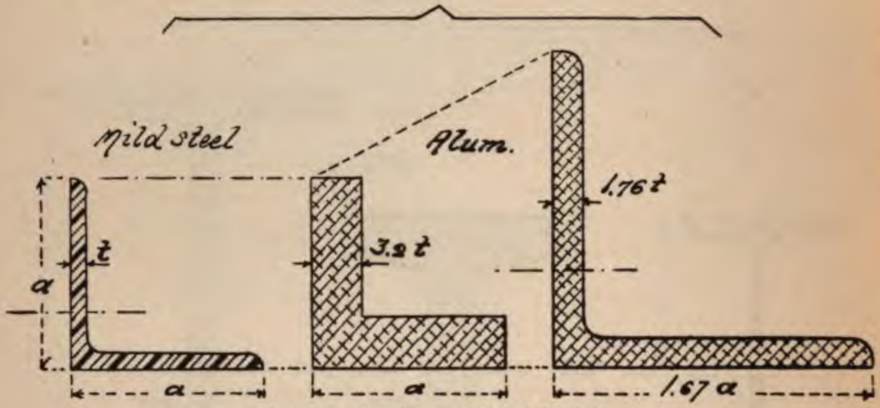


FIG. 10.—Sections of Equal Weight.

First when the depth of ∠ is the same.

Ratio of moments of inertia, $\frac{I'}{I} = 4.61$

When worked to the ultimate limit, $\frac{M'}{M} = 1.56$

When worked to the elastic limit, $\frac{M'}{M} = 2.4$

$$\frac{f'}{f} = \frac{1}{1.54}.$$

Next when the *depth is proportioned.*

Ratio of moments of inertia, $\frac{I'}{I} = 6.91$

When worked to the ultimate limit, $\frac{M'}{M} = 2.35$

When worked to the elastic limit, $\frac{M'}{M} = 3.59$

$$\frac{f'}{f} = \frac{1}{2.3}.$$

b. Shapes giving equal bending moments.
(1). I *Beams.* Figs. 11 and 12.

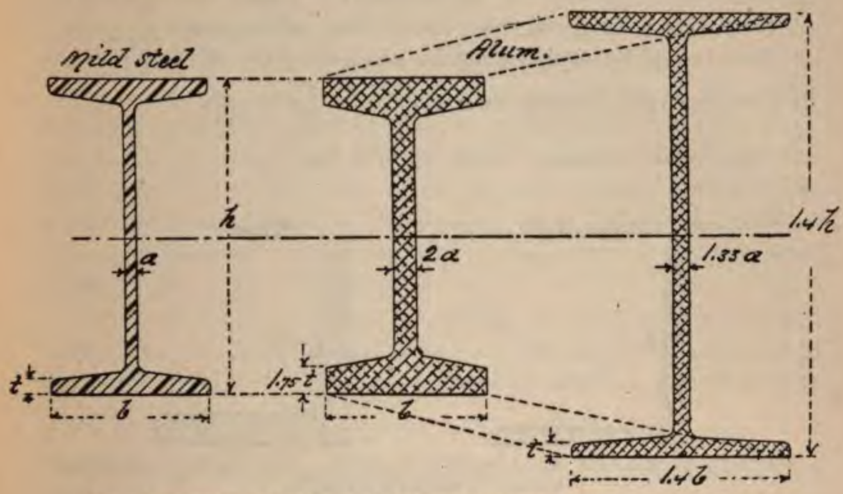


FIG. 11.—Sections for Equal Bending Moments. Fiber under ultimate compressive strength.

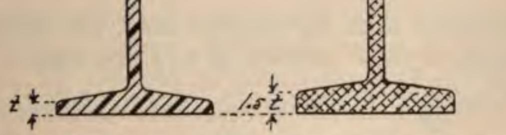


FIG. 12.—Sections for Equal Bending Moments. Fiber compressed to elastic limit.

First, when designed from the *ultimate limit of resistance.*
Fig. 11.—When the *depth* is the *same,* the ratio of cross sections is 1.67, the *ratio of weights is* 0.553 and $\frac{f'}{f} = \frac{1}{.59}$.

When the *depth is proportioned*, the ratio of cross sections is 1.39, the *ratio of weights* is 0.46 and $\frac{f'}{f} = \frac{1}{.82}$.

Next, when designed from *elastic limit of resistance.*

Fig. 12.—The *depth* being the *same*, the ratio of cross sections is 1.11, the ratio of *weights is* 0.37 and $\frac{f'}{f} = \frac{1}{.38}$.

(2). *Angle bars* ∠. Figs. 13 and 14.

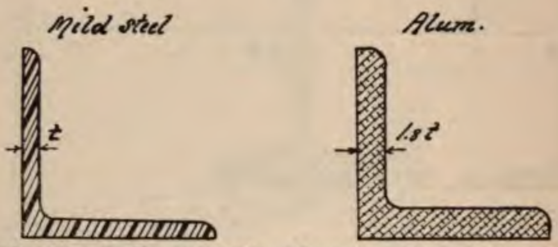


FIG. 13.—Sections for Equal Bending Moments. Fiber under compression worked to ultimate strength.

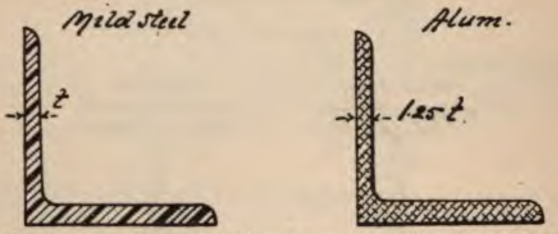


FIG. 14.—Sections for Equal Bending Moments. Fiber under compression worked to elastic limit.

When designed from the *ultimate limit*, the *depth* being the *same*, the ratio of cross sections is 1.74, the *ratio* of *weights* is 0.58 and $\frac{f'}{f} = \frac{1}{.58}$.

When designed from the *elastic limit*, the *depth* being the *same*, the ratio of cross sections is 1.19, the *ratio* of *weights* is 0.396 and $\frac{f'}{f} = \frac{1}{.38}$.

The above comparisons for resistance to bending and for stiffness give the following results, namely:

1. For bars of square section, giving the same ultimate tensile strength, the ultimate bending moment that each can resist is practically the same, the aluminum bar giving 1.04 times the resistance of the steel bar, while the bending moment before the elastic limit is reached is half as large again for aluminum, the ratio being 1.6. On the other hand, the steel bar is the stiffer of the two, the deviation or flexion produced by the same force being but three-quarters that of the aluminum bar. Thus the aluminum bar, giving the same ultimate tensile strength, an equal ultimate resistance to bending, three halves as great an elastic resistance to bending, of three-quarters the stiffness, weighs half as much as the steel bar.

2. For bars of square section, giving the same elastic strength in tension, the aluminum bar gives 0.6 the ultimate resistance to bending and 0.96 the elastic resistance to bending, is 0.38 only as stiff, but weighs about a third as much as the steel bar, $\frac{1}{2.8}$.

3. For bars of square section, giving the same ultimate strength of compression, the aluminum bar gives 1.33 times the ultimate resistance to bending, and 2.03 times the elastic resistance to bending, is about of equal stiffness and weighs about 0.59 as much as the steel bar.

4. For bars of square section, giving the same elastic strength of compression, the aluminum bar gives 0.7 the ultimate resistance to bending and 1.07 times the elastic resistance to bending, is but 0.44 as stiff and weighs about 0.38 as much as the steel bar.

5. For bars of square section of the same weight the aluminum bar, giving 2 times the ultimate resistance to tension, 2.8 times the elastic resistance to tension, 1.7 times the ultimate resistance to compression, 2.6 times the elastic resistance to compression, 1.875 times the ultimate resistance to shear, gives in addition 2.94 times the ultimate resistance to bending, 4.5 times the elastic resistance to bending and 3 times the stiffness.

6. For plates of rectangular sections of the same width, giving the same ultimate strength of tension, the aluminum plate, of half the weight, gives 1.26 times the ultimate resistance to bending, 1.94 times the elastic resistance to bending and 1.125 times the stiffness.

7. For plates of rectangular section of the same width, giving

the same elastic strength of tension, the aluminum plate, of about one-third the weight, gives 0.65 the ultimate resistance to bending, 0.99 the elastic resistance to bending, and 0.41 the stiffness.

8. For plates of rectangular section of the same width, having the same weight, the aluminum plate, giving twice the ultimate resistance to tension, 2.8 times the elastic resistance to tension, gives in addition 5.1 times the ultimate resistance to bending, 7.8 times the elastic resistance to bending, and 9 times the stiffness.

9. For I beams of the same weight and proportioned sections, the aluminum beam gives 2.83 times the ultimate resistance to bending, 4.45 times the elastic resistance to bending, and 3.1 times the stiffness.

10. For angle bars of the same weight and proportioned sections the aluminum angle gives 2.35 times the ultimate resistance to bending, 3.59 times the elastic resistance to bending, and 2.3 times the stiffness.

11. For I beams of proportioned sections, giving the same ultimate resistance to bending, the aluminum beam has 1.39 times the area of cross section, has 0.46 the weight and 0.82 the stiffness.

12. For I beams of the same depth, giving the same elastic resistance to bending, the aluminum beam has 1.11 times the area of cross section, 0.37 the weight and 0.38 the stiffness.

13. For angle bars of the same depth, giving the same ultimate resistance to bending, the aluminum angle has 1.74 times the area of cross section, 0.58 the weight and 0.58 the stiffness.

14. For angle bars of the same depth, giving the same elastic resistance to bending, the aluminum angle has 1.19 times the area of cross section, 0.39 the weight and 0.38 the stiffness.

Of the above results, whose applications to marine construction are pointed out below, the most striking and most significant are those indicating the possibilities of strength with limited weight.

Thus, for equal weight, in the case of square sections not designed primarily for bending, whose simple resistance as seen is about twice as great for aluminum for the ultimate limit and nearly three times as great for the elastic limit, the resistance to bending is nearly three times as great at the ultimate limit and four and a half times as great at the elastic limit, with three times the stiffness.

This advantage of greater resistance to bending and greater stiffness, thus pronounced for square sections, is enormously greater for plating. With the same weight the aluminum plate offers over five times the ultimate resistance to bending, nearly eight times the elastic resistance to bending, and is nine times as stiff.

These remarkable results flow from the great moment of inertia in the case of aluminum sections, the metal added to supply the increase of area of cross section acting with large leverage about the neutral axis. The aluminum plate being three times as thick, the moment of inertia is twenty-seven times as great. This enormous increase in stiffness, as will be seen below, is of great advantage in the case of thin plates, which are necessarily deficient in stiffness.

When resistance to bending and stiffness are themselves the objects of design, determining a form of section of large moment of inertia, with the usual shapes, such for instance as I beams and angle bars, the advantages offered by aluminum are more pronounced than in the cases of simple resistance. With equal weight it may be said broadly that the aluminum beam gives two and a half times the ultimate resistance and is two and a half times as stiff. The effect of aluminum's high fraction of elasticity is again striking; when compared for elastic resistance the aluminum beam gives about four times the strength.

Inversely, to produce a given ultimate resistance to bending the aluminum beam has about half the weight, though it is not quite so stiff, and to produce a given elastic resistance the aluminum beam has less than four-tenths the weight, but is only half as stiff.

The above comparisons for simple resistance and for resistance to bending and stiffness, all so heavily in favor of aluminum, are not complete, however, for passing upon the two metals from the standpoint of strength, for the forces implied are statical or else are applied gradually, while in the actual service of usual structures, particularly marine structures, the forces are dynamic and are applied with full effect from the start. The comparison to be complete must therefore extend to resistance to dynamic forces.

C.—Comparison for Resistance to Dynamic Forces.

Movement, wherever found, represents energy and is the result of work done, and its destruction requires antagonizing energy, antagonizing work. A force, however great, unaccompanied by movement, generating no energy, doing no work, could extinguish no energy of movement. To extinguish energy, the antagonizing force must retreat, and the amount of energy extinguished results not only from the magnitude of the force, but also from the distance of its retreat. If the resisting force varies in magnitude, the antagonizing work done is the integral of the products of the successive forces by the elementary distances, or is equal to the product of the mean force by the distance.

For comparing the resistance to dynamic forces of steel and aluminum it is thus necessary to determine or compare the mean force or resistance that each offers and the distance through which the resistance acts. Taking for the purpose of the comparison the case of tension, the force within the elastic limit starting at zero is proportional to the extension, so that the mean force up to the elastic limit is equal to half the force at the limit. This gives for steel a mean force of 15,000 pounds per sq. in., and for aluminum a mean force of 14,000 lbs. per sq. in. The elastic extension for mild steel being taken at $\frac{1}{8}$ of one per cent, the work done within the elastic limit is $15000 \times 0.00125 = 18.7$ foot pounds per square inch of cross section for each foot of length.

Data is lacking on the direct measurement of the elastic extension of aluminum, but according to Hütte, referred to above, the modulus of elasticity of aluminum is 10,000,000. The modulus for mild steel being taken at 30,000,000, the same force would produce three times more elongation in aluminum. If the elastic limit reached 30,000 lbs. per sq. in., the elongation would be $\frac{3}{8}$ of one per cent. Reaching only 28,000 lbs. per sq. in., the actual elongation would be $\frac{28}{30} \times \frac{3}{8} = \frac{7}{20}$ of one per cent. The work done, therefore, within the elastic limit is $14000 \times 0.0035 = 49$ foot pounds per square inch of cross section for each foot of length. The work done within the elastic limit per unit area of cross section is therefore 2.61 times greater in aluminum than in steel, as illustrated in Fig. 15. With the same weight the work done by the aluminum piece, which would have three times the area of cross section, would be 7.83 times as great.

When it is recalled that structures, particularly marine structures, are subject to repeated dynamic forces, which on account of their repetition must be extinguished within the elastic limit, since they would entail destruction if this limit were passed; when it is recalled, thus, that the bulk of usual structural resistance is resistance to dynamic forces within the elastic limit, the above remarkable result takes on the aspect of a most serious advantage, an advantage for aluminum that is overwhelming where the structure is not liable to be subjected to an unusual or extraordinary force. When, however, a single, unusual force is liable to be brought to bear, as frequently the case in marine structures,

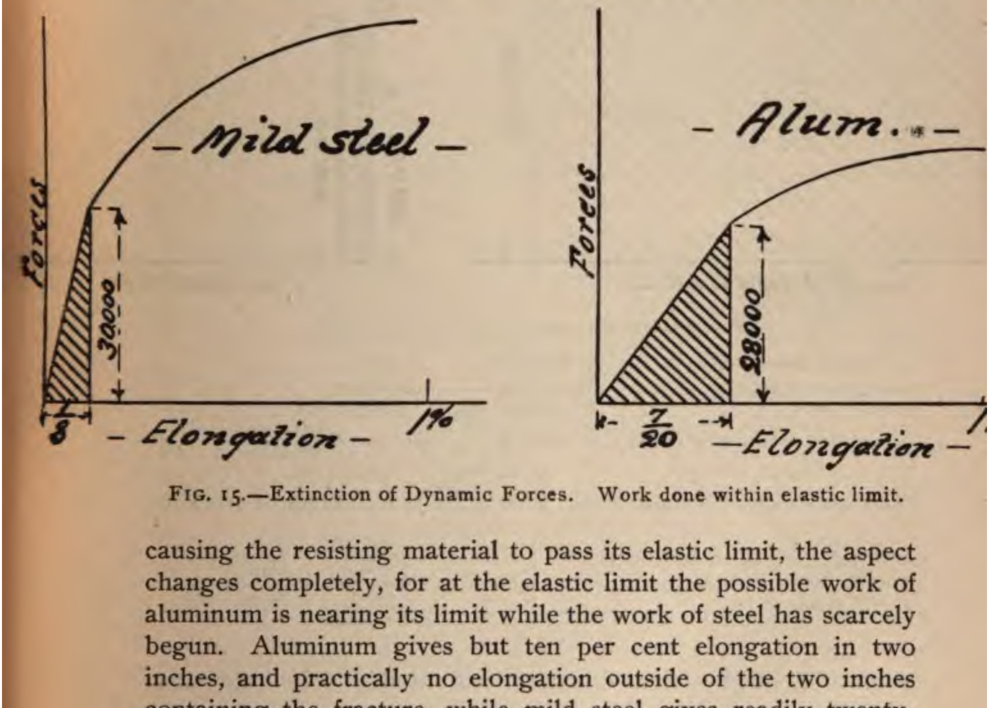


FIG. 15.—Extinction of Dynamic Forces. Work done within elastic limit.

causing the resisting material to pass its elastic limit, the aspect changes completely, for at the elastic limit the possible work of aluminum is nearing its limit while the work of steel has scarcely begun. Aluminum gives but ten per cent elongation in two inches, and practically no elongation outside of the two inches containing the fracture, while mild steel gives readily twenty-five per cent elongation in eight inches, and the elongation extends to parts far removed from the point of fracture. Thus when the elastic limit is passed, the bulk of the aluminum piece ceases to lend adequate additional assistance, throwing same upon the narrow region of ultimate fracture, while with steel the whole bulk of the piece continues to contribute proportionately to the end.

It is almost as though the whole volume worked with steel, while only a section worked with aluminum, and the ratio of the two is roughly proportional to the length. For pieces of even moderate length the difference in work done is enormous, as illustrated in Fig. 16. Thus against a single, isolated, abnormal, destructive dynamic force, steel gives an overwhelmingly larger

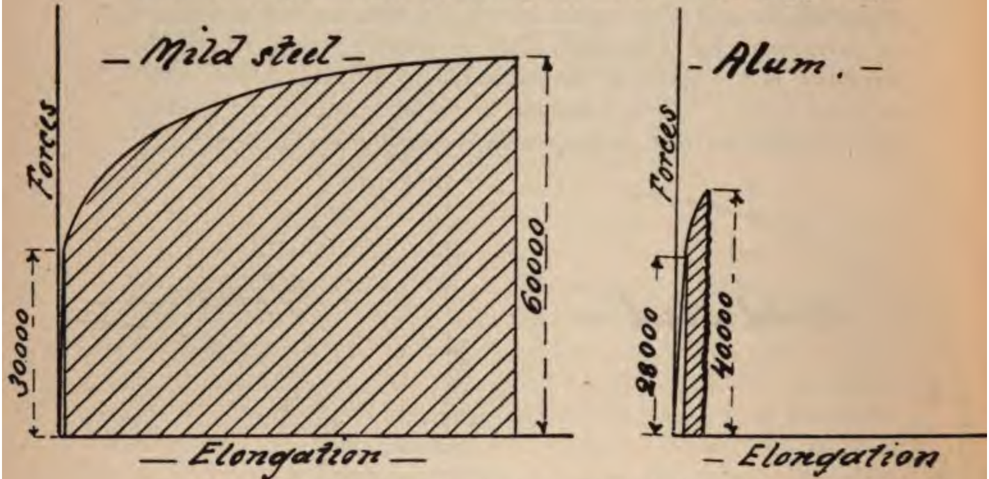


FIG. 16.—Work done beyond Elastic Limit.

Data for Curves, Figs. 15 and 16.	Mild Steel.	Alum.	
Modulus of elasticity,	30,000,000	10,000,000	
Elastic limit,	30,000 lbs.	28,000 lbs.	
Elongation within elastic limit,	$\frac{1}{8}$ of one %	$\frac{7}{20}$ of one %	(deduced from modulus of elast.)
Ultimate tensile strength,	60,000 lbs.	40,000 lbs.	

Work done within the elastic limit, $W = \frac{1}{2} \frac{S^2}{E} \times V$, the ratio of work done.

S = lbs pr. sq. in. at elastic limit,
E = Modulus of elasticity,
V = Volume of body,

is thus, $$\frac{\frac{30000^2}{30000000}}{\frac{28000^2}{10000000}} = \frac{30}{78.4} = \frac{1}{2.61}.$$

guarantee, but for usual dynamic forces, liable to be indefinitely repeated, aluminum offers enormous advantages.

The application of the results of the above comparisons of advantage and disadvantage from the standpoint of strength and weight are treated below, but these alone are not final in determining the choice between two metals; another important factor enters, namely, cost.

(*To be concluded in No. 83.*)

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

ON THE PERFORATION OF FACE-HARDENED ARMOR.

By Cleland Davis, Ensign, U. S. Navy.

In the following article the writer has endeavored to briefly summarize a theory of the resistance of face-hardened armor and the action of projectiles, both plain and capped, on impact, with the further object of presenting perforation formulas derived from experiments at Indian Head.

Prior to the advent of face-hardened armor formulas for the penetration of wrought-iron and homogeneous steel plates were based on the assumption that the projectile experienced no change of form while passing into and through the target. With face-hardened armor, however, such a thing rarely happens under the conditions of test except when the plate is far outmatched by the projectile, as when the projectile is of extraordinary quality, or the plate decidedly inferior.

As the result of experience in the United States it is not believed that a good formula based upon anything but complete perforation can be constructed to express the relation between gun and plate on impact, when the latter is face-hardened. In homogeneous plates the penetration is always proportionate to the energy of impact, and the resistance offered is largely local, closely corresponding to the action of punching. The action of resistance is radically different with face-hardened armor. The inextensibility of the hard face and its inability to bend or flow transmits the strain of impact to the tough back, and distributes it over a considerable area, thus bringing to bear all the resisting power of that portion of the plate to check the advance of the projectile. If the projectile has sufficient remaining energy pene-

tration ensues, otherwise the projectile smashes harmlessly on the plate. The first effect is to elastically dish the hard face; when the limit of strain is reached this gives way, and the resistance then becomes largely local; hard jagged fragments of the surface are carried into the body of the plate, scoring and abrading the ogival of the projectile and impeding its advance. The further function of the hard face is to prevent the flow to the front of displaced metal of the plastic body. Sometimes, when the projectile remains undeformed and the hard face is circumferentially broken to a diameter considerably greater than the caliber of the projectile, a front fringe appears around the shot hole; this of course decreases the total resistance to penetration.

It will thus be seen that the function of the hard face is threefold, of which the first mentioned is by far the most important. There is a definite limit of velocity corresponding to a considerable proportion of the total energy required for perforation, below which the projectile makes practically no impression on the plate, except perhaps a saucer-like depression enclosed by fine concentric cracks in the hard face. A 5-inch Carpenter projectile with a striking velocity of 1522 f. s. hardly marred the surface of a Carnegie 4-inch plate, while a velocity of 1977 f. s. just effected perforation. An 8-inch Holtzer projectile, striking a Bethlehem 10-inch plate at a velocity of 1498 f. s., failed to break the hard face.

The theory of the resistance of face-hardened armor, now generally accepted in this country, was first enunciated by Lieut. A. A. Ackerman, U. S. Navy, and his deductions have been fully borne out by subsequent experiments. It seems to be the popular impression that the resisting power of armor due to the action of the hard face is derived from its power to fracture the shot's point, with a subsequent smashing and pulverizing progressively from the point.

It is difficult to see how this theory can be reconciled to the results of the great number of experiments conducted in this country. On such an hypothesis disintegration of the projectile must commence the instant the point reaches the face, and the successive layers or particles of metal shearing and sliding over one another and the whole breaking into a myriad of fragments, thus distributing the remaining energy among the particles and rendering the aggregation powerless to do harm. When partial

penetration is effected some of these fragments are supposed to act together as a unit, combining their energy—the whole mashing into the indent and forming a coherent mass that remains sticking in the plate.

On impact the following cases represent the action of the projectile depending upon the caliber of gun, thickness of plate, weight of projectile, quality of projectile and plate, and striking velocity:

1. Where complete perforation is effected, the projectile remaining intact or only slightly deformed. In nearly every instance where the projectile is upset, the diameter is increased around the bourrelet, and where there are signs of rupture cracks appear extending parallel to the axis emanating evidently from the upset portion, and forming ribbon-like strips evenly distributed around the circumference. 2. Sometimes a section of the plate is punched out to a diameter equal to or slightly exceeding the caliber of the projectile, the shell being broken up and part of the head remaining apparently welded into the face of the section punched out. (This is not usual in the United States where the plate is just perforated, though from the reports it seems to occur abroad, especially in Germany, in almost every instance where bare perforation ensues.) In this country the plate usually gives way in the rear by rupture along lines radiating from the center of the back bulge. Sometimes the punched-out section is found intact, and this usually occurs when the plate is much overmatched. The punched-out section is then nearly always in the form of an obtuse cone. 3. Where the head remains sticking in the plate. Sometimes, but rarely, the point and ogival remain undeformed, but usually the ogival is mashed into a mushroom-like mass, breaking away the shot-hole to a diameter sometimes 50 per cent larger than the caliber of the projectile; this is caused by its upsetting at or near the bourrelet. The apex of the powder chamber is invariably preserved when the penetration is appreciable. 4. Where the projectile rebounds, being shattered on impact, or remaining intact or slightly deformed. In the latter case the same effect is observed as when perforation occurs, namely, bulging at the bourrelet with a tendency to rupture along longitudinal lines extending through the bourrelet.

Often the point is broken or sheared off when the impact is not normal. It is rare that the axis of the projectile is normal to the

tangent plane of the surface at the moment of impact. Even when striking at a considerable angle the projectile turns and enters the plate normally, following the line of least resistance. It is this lateral component of the blow at an angle to the axis that causes the breaking off of the point, the projectile often remaining otherwise undeformed after perforation or rebounding. The fracture in such cases is always clean, with no evidence of a sliding motion over one another of the particles, showing that in the case of perforation the point is carried through the plate, becoming detached afterward. Occasionally, when the projectile is of excellent quality, but the velocity unequal to perforation, the head of the projectile remains sticking in the plate apparently undeformed. A Krupp face-hardened plate exhibited at the World's Fair at Chicago in 1893 showed this strikingly. The back bulge on this plate was so cracked as to show the point plainly visible and apparently perfect in form.

The action of the projectile on impact with regard to rupture may be stated as follows: The first tendency is to bulge at or near the bourrelet; this is due to longitudinal compression and is what would be expected. At the moment of impact the greatest strain is on the point, but this does not give way locally, being in the first place superior in quality to the metal of the plate (and this latter would therefore give way first where the energy is sufficient to effect penetration at all), and in the second place being supported by the form of the ogive, which may be compared to an arch of which the point is the top. The strain is thus transmitted to the body of the projectile, which causes it first to bulge and then to crack longitudinally in response to the transverse component of the blow. When the head effects an entrance and the plate is not perforated, the hard envelope of the ogival is usually flaked off and the more plastic metal of the interior is moulded into a mushroom-like mass, not rupturing because of the support of the metal of the plate. Sometimes, however, the tempered surface of the ogive remains intact. This rarely occurs in partial penetration, but is nearly always the case when complete perforation ensues, all parts of the projectile getting through the plate. In the latter event when rupture occurs, the head breaks up along its weakest lines.

Finally, in all cases, fragments found either in front or in rear of the plate present clean fractures, except where the pieces are

evidently marred by contact with the plate; the lines of fracture of the body are at right angles and parallel to the axis, and the exterior surface of the fragments (except in the cases cited before, where the hard envelope of the ogive is flaked off) shows that there was little or no deformation before rupture.

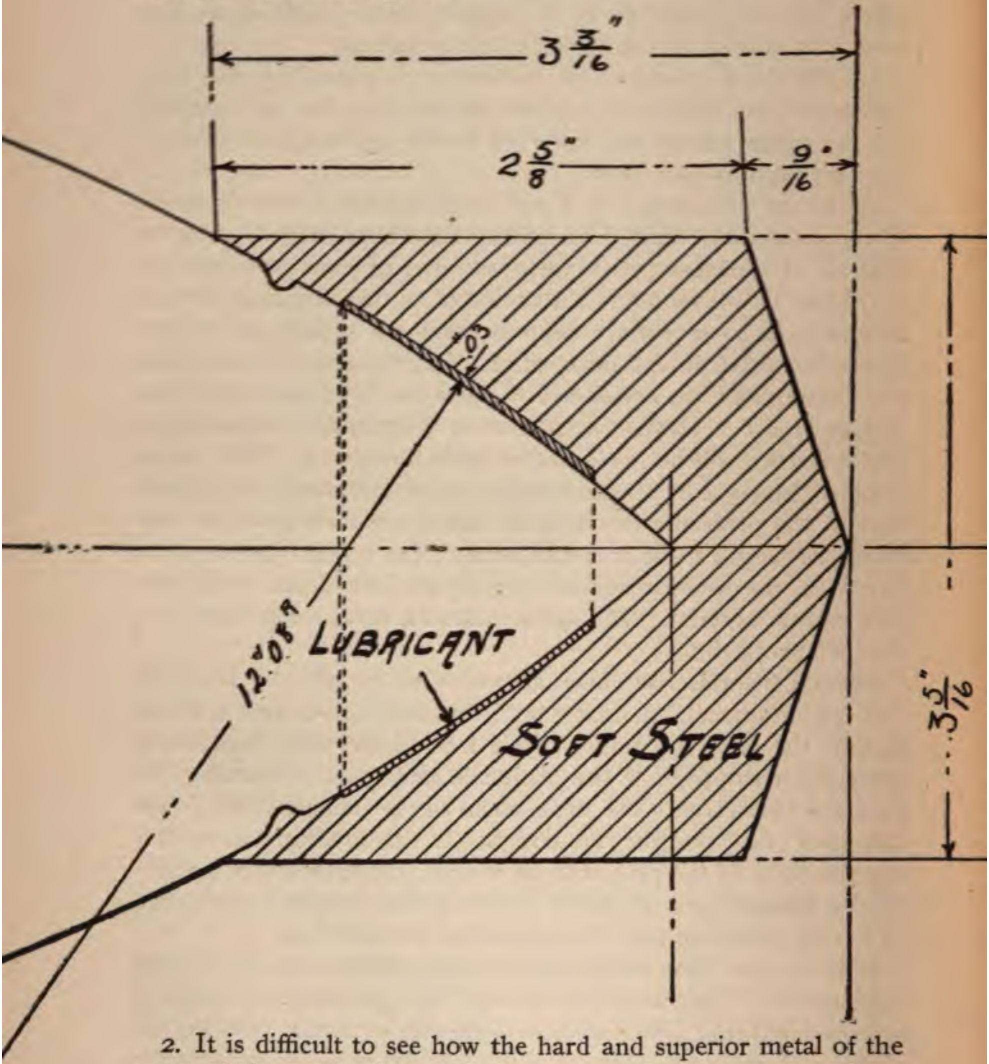
In effect the concentrated resistance presented by the face-hardened plate checks the advance of the projectile, and the sudden stoppage causes the latter to break up along its weakest lines through its own inertia.

As to the advantages of a soft steel cap fitted over the point of the projectile. Many experiments have been carried on by the Bureau of Ordnance with various forms of caps presented by Mr. Isaac G. Johnson and with some of its own devising, and the results have so uniformly demonstrated the superiority of projectiles so fitted in the penetration of face-hardened armor that the Department has decided to fit them to all service projectiles. A tabular list of all these experiments is appended to this article and reference will be made to this table further on. The cap, as adopted, consists of a cylindrical piece of soft steel, half the caliber of the projectile in diameter, bored out to a depth of two-thirds its length to fit over the head of the ogival. A recess or cavity in the interior surface, .03 of an inch deep, contains a lubricating material. The sketch shows a service cap fitted to a six-inch projectile.

Several theories have been advanced to explain the action of this cap on impact. 1. Some hold that it acts as it were a buffer against the hard and impenetrable face of the plate, preventing the sudden stoppage of the projectile and greatly lessening the shock of impact. 2. The main claim of the patentee, Mr. Johnson, is in effect that the cap, completely surrounding and enclosing the point of the projectile, as it does, strengthens the projectile by supporting it all around, thus giving increased resistance to lateral deflection and to longitudinal compression.

It is believed that neither one of these theories offers the true explanation. The fallacy of the first becomes apparent when it is considered that if the function of the cap is merely to lessen the shock of impact, the same results could be achieved by firing a projectile without a cap at such a reduced velocity that it will strike the plate at the same velocity as the capped projectile had after piercing the cap. In other words, unless the cap in some

manner weakens the plate or strengthens the projectile it can only reduce the velocity with which the point of the projectile meets the face of the plate.



2. It is difficult to see how the hard and superior metal of the point of the projectile can derive any considerable support from the soft metal of the cap, offering as it does but an insignificant resistance to longitudinal and transverse strains. Certainly it cannot resist materially the compressive strains due to impact.

Possibly the cap may be a slight aid to the point in preventing it from being broken off when the impact is oblique, but it is believed that the cap is disintegrated in this case before the shearing strain comes on the point. This theory was no doubt derived from the supposition that projectiles crush progressively from the point. If the cap is ruptured, as would seem to be the case, before the point of the projectile reaches the face of the plate, the cap would operate merely to reduce the striking velocity.

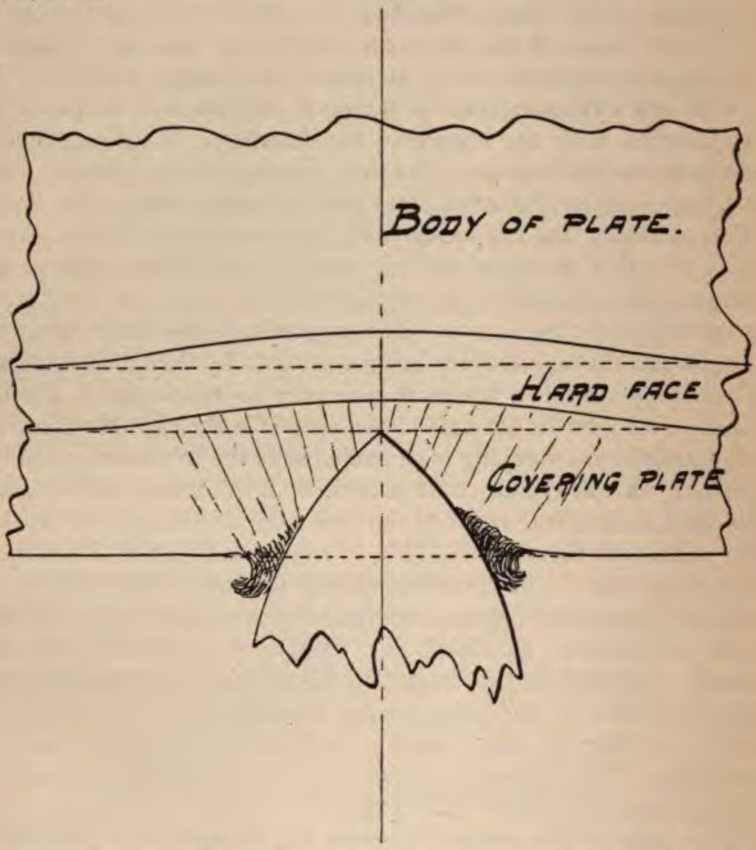
The true explanation of the action of the cap must be taken in conjunction with the theory of the resistance of face-hardened armor enunciated before. The cap, meeting the face of the plate at a high velocity, dishes or depresses the hard surface to the limit of its elasticity, the cap being itself destroyed in so doing. And to be effective, therefore, the cap must have sufficient stiffness or longitudinal strength to accomplish this; possibly the hard face is crushed in by this action. The projectile meanwhile is advancing, its way through the cap being smoothed by the lubricant, and when the point meets the plate resistance to its advance is purely local. Possibly the passage of the projectile through the plate is facilitated by the carrying in of sufficient of the lubricant and portions of the soft cap to cover asperities in the metal and prevent the hard jagged fragments of the face from scoring and abrading the surface of the ogival. This, it is believed, is the true function of the cap. The comparative ease with which face-hardened armor is perforated when a thin plate of wrought iron is placed over the surface, as shown by Russian experiments, can be readily explained on this theory, by considering the wrought-iron metal opposed to the point of the projectile at the moment of impact to bear the same relation as the cap to the point of the projectile. The action is explained in the following somewhat exaggerated sketch (see next page):

The point of the projectile enters the wrought-iron plate and the stress of impact is transmitted to the hard face along lines normal to the ogival, depressing the surface to the limit of its elasticity, so that when the point reaches the plate, although its velocity is reduced, the resistance it encounters is not concentrated but is local. The breaking in of the hard face by the superior metal on the point of the projectile is then comparatively an easy matter.

Various forms of these caps have been tried at Indian Head

with more or less definite results. The following, however, seem to be conclusively established:

1. That a projectile fitted with a solid cap of the form finally adopted, but containing no lubricant, is superior to an uncapped projectile.



2. That a cap in the form of a hollow cylinder with thick walls, containing no lubricant, is equally as efficient as the solid cap containing no lubricant. This goes far toward proving the theory that the effect of the cap is to weaken the plate rather than strengthen the projectile.

3. That a thin-walled envelope filled with lubricant does not facilitate penetration.

4. That the most effective form is a thick-walled cap or envel-

ope, strong enough to withstand considerable strain before rupture, yet plastic enough to permit of some deformation before breaking, combined with a lubricant contained in a recess or cavity surrounding the point of the projectile. Soft steel seems to be the best material for the cap, though experiments have shown copper to be very efficient.

In the *London Engineer* of July 3rd, 1896, there is an article entitled, "Herr Krupp on the Perforation of Steel Armor," in which is mentioned a formula recently propounded by Krupp as applicable to the perforation of the best and newest plates with hardened faces. The original formula given in continental units is $p\,v^2 = 5800\,a\,e^2$, where v is the striking velocity in meters, p the weight of the projectile in kilos, a the diameter of the projectile in cm., and e the thickness of the plate in cm. Translated into English units this formula becomes

$$e^2 = \frac{pv^2}{a}\,\frac{1}{\log^{-1} 6.3532}$$

Certainly, the writer says, this is the simplest and oldest form of Fairbairn's equation. As originally deduced, based upon statical experiments, by punching iron plates under the machine, using cast, wrought and steel punches with round and flat ends, and starting with the hypothesis that the work expended by a shot in piercing a plate was equal to the striking energy, his formula was of the form $e^2 = \frac{pv^2}{a}.\ C$, which is identical with the above.

According to Krupp, continues the writer, we may now take it as based on the best formula that can at present be suggested. And being founded on correct principles, the formula will no doubt be fairly accurate if the constant is changed to meet changed conditions so long as the projectile is assumed to pass into and through the target unbroken and undeformed.

Experiments ranging over a period of several years, comprising the attack of face-hardened armor by guns of all service calibers up to and including the 13-inch, have been carried on by the Bureau of Ordnance, under the direction of Captain W. T. Sampson, U. S. Navy, at the Naval Ordnance Proving Ground at Indian Head. The similarity of conditions in these experiments, in quality of armor and projectile, of gun and charge, furnishes reliable data from which a formula can be evolved that will

express with fair accuracy the relation between the perforating power of the projectile and the resisting power of the plate.

A table is appended giving the details of those experiments that were chosen as being of a thoroughly representative character. In a large majority of these cases where perforation ensues the energy of the projectile was just sufficient to overcome the resisting power of the plate, completing perforation with but slight surplus energy, the plate cracked possibly and the projectile set up, deformed or disintegrated, the pieces lodging in the backing or in the butt. In a great many cases reservation must be made due to the weakening of the plate from previous impacts.

It might here be stated that where plate and projectile are practically evenly matched, being of good quality, both are strained nearly to the limit of rupture, and when this occurs either in one or the other it does not mean a considerable increase in the consumption of energy beyond that taken up by the strains of impact. Assuming, then, an equation of the form $e^x a^y C = p V^2$, it will readily be seen that such indeterminate elements as the cracking of the plate, breaking up of the projectile, dissipation of energy in the form of heat, can, by considering the absorption of energy in these ways to bear the same proportion in all cases to the total striking energy, be included in the constant. This equation is fundamentally sound. It was first elucidated by Fairbairn on the hypothesis that the destructive power of a shot was due to its energy, and has since formed the basis of all formulas for the penetration or perforation of armor.

Having, then, data deriving considerable reliability from similarity of conditions, it becomes easy to evolve a formula that will express within limits, allowing for difference in quality of plate and projectile, the results of the laws of destruction, though of course such an expression being empirical, the laws themselves cannot be definitely stated.

By the method of least squares the most probable values of the exponents and of the constant were found to be contained in the following expression:

$$V = \frac{a^{1/6} e^{3/4}}{p^{1/2}} \log^{-1} 3.34512,$$

where V = striking velocity in foot seconds;
a = caliber of gun in inches;
e = thickness of plate in inches;
p = weight of projectile in pounds.

As before stated this formula expresses the relations between the elements only when perforation ensues. From it can be determined the minimum velocity sufficient to perforate a plate of given thickness, or the maximum thickness of plate that can be perforated by a projectile of given velocity. The non-deformation of the projectile is not assumed, but the formula is based on data where the energy of the projectile was barely sufficient to accomplish perforation, the projectile being broken up and the pieces passing through the plate.

Perforation Table.

(Calculated from the above formula.)

Gun.	Plate.	Velocities.	Gun.	Plate.	Velocities.
4″	3	1757	6″	5	1813
	4	2180		6	2078
5″	4	1980		7	2333
	5	2343		8	2579
	6	2683	10″	10	1760
8″	8	1884		11	1891
	9	2058		12	2019
	10	2227		13	2143
	11	2392		14	2266
12″	12	1696		15	2386
	13	1801	13″	13	1648
	14	1904		14	1742
	15	2005		15	1834
	16	2104		16	1925
	17	2202		17	2015
				18	2103

This table now forms the basis from which the velocities for acceptance tests of armor and of projectiles are obtained.

It is believed that this formula represents, with as much accuracy as could be expected in an empirical expression, the present status of the relation between armor and projectile in the United States.

In this connection it is interesting to compare the results of some of the latest trials abroad, especially those of Krupp, with experiments in this country, and by means of the formula they can be reduced to a definite basis, with reservations allowing for differences in quality of plate and projectile. It is to be regretted that there are but meagre data relative to experiments on face-hardened armor in England and France that will serve for comparison as to relative merit. England has only lately come to

adopt nickel steel armor for general use, and the recent ballistic trial of a 6-inch plate representing a lot of armor for the Canopus type shows this plate to be up to the average for that thickness. As yet, however, they have gone no further.

In Germany there are records of many experiments against plates of different thicknesses, which, while not so extensive as those made in the United States, are still sufficient to give a fair idea of comparative value. There is no question but that Krupp armor is at least the equal of if not superior to that of England, France, Austria and Russia. Experiment indicates the latter; hence the other countries will not suffer if Germany is taken as the European representative in comparing the quality of American armor with that made abroad.

Some of Krupp's most recent experiments are tabulated and appended with columns showing the velocities required for perforation under the same conditions calculated from the proposed formula and from the one quoted before as being that presented or used by Krupp. The agreement in the former case with the actual results is striking. The velocities given by the Krupp formula seem to be entirely at variance with the actual results for the thicker plates; too much value is given to slight variations in thickness of plate. Captain Castner, however, states in an article published in "Stahl und Eisen" in April, 1896, referring to the Krupp formula: "Whether this formula can also be applied to thick plates is, according to the assertion of the Krupp works, still unsettled, as such plates have not yet been perforated."

These experiments of Krupp with the larger plates were evidently conducted with the view of obtaining the actual velocities required for the perforation of the plates. The truly remarkable agreement of the calculated with the actual velocities as given by these experiments shows that much reliability can be given to the proposed formula as a basis for comparing the resisting qualities of German and American armor. An examination of the tabulated results of these experiments at Indian Head, upon which the formula is based, carried on during a period of several years, shows a constant and steady improvement in the quality of Carnegie and Bethlehem armor. Attention is called to the Bethlehem 8-inch plate, manufactured for the Maine's turret and tested October 2, 1894. As regards resistance, the best service plate yet tested was a Carnegie 12½-inch reforged, face-hardened plate,

B. 491, manufactured for the forward 13-inch B. L. R. barbette of the Kearsarge.

The plate had previously been attacked by two 10-inch Holtzer A. P. shell, the second of which made a diagonal crack 5 feet long and 7 inches deep in the back of the plate. This plate was attacked by a 12-inch Carpenter projectile weighing 850 lbs. with a striking velocity of 1932 f. s. and a striking energy of 21,940 tons. The back bulge was driven out, but no part of the projectile, which broke into 79 pieces, got through the plate. This velocity under similar conditions would, by the formula, have sufficed for the perforation of a 14.3-inch plate. The projectile, as stated by the Inspector of Ordnance, gave every indication of being an excellent one. The plate was through cracked and broken into three pieces, lines of fracture radiating from this impact and passing through place of impact No. 2.

By the formula, using the weight of a Krupp or St. Chamond 12-inch A. P. projectile, 716 lbs., a plate of the thickness of 14.3 inches requires a velocity of 2107 f. s. to perforate, which, in the experiments on plate 575-A, was shown to be just sufficient for the perforation of a plate 13.78 inches thick. This latter plate seems to have been more resisting than its companion 14.49-inch plate, 575-B, and slightly superior to the average of American plates as shown by the formula. Therefore the 12.5-inch Carnegie plate would seem to be equal in resistance to a 13.78-inch Krupp plate. There are several considerations, however, that must be taken into account affecting the final comparison of superiority. The Krupp plate was experimental and no doubt manufactured with the utmost care with the view of obtaining the most resisting plate; the Carnegie plate was chosen from a lot of twenty-two as promising to make the poorest showing ballistically of all. On the other hand, the Carnegie plate was practically destroyed, being cracked and broken into three pieces, while the Krupp plate was not through cracked, being indeed hardly cracked at all; such cracks as did develop being confined practically to the surface, and radiating from the point of impact to the edges. The greatest depth of these cracks was about two inches. Again, the greater weight of the Carpenter projectile is no inconsiderable factor even though the energy of impact in both cases is the same.

Weighing these considerations, then, it would seem that the Carnegie and Krupp plates were of about equal merit, the super-

ior resisting power of the one being balanced by the greater toughness and tenacity of the other.

The most resisting plate that Krupp has yet produced is the 11.8-inch plate tested at Meppen in September, 1895. This plate withstood the impact of a Krupp 712.6 lb. A. P. projectile with a striking velocity of 1993 f. s., being practically uninjured save three surface cracks, the greatest depth of which was 3.1 inches. The plate was not perforated; the depth of penetration was not given, but from the fact that the back bulge was 3 inches high and slightly cracked it would appear that the limit of resistance had been almost reached. A Carnegie 12-inch experimental reforged face-hardened plate, tested at Indian Head on May 29, 1897, compares very favorably with this star plate of Krupp. The Carnegie plate was 12 feet long, 8 feet wide and 12 inches thick, and was backed by 12 inches oak and two ½-inch skin plates, the backing being secured to the plate by 18 2.8-inch armor bolts. In shape the plate was flat, rectangular. It was attacked first by a 12-inch Holtzer A. P. projectile weighing 850 lbs., striking with a velocity of 1811 f. s. The impact was 6 feet 2 inches from the right edge and 3 feet 8 inches from the bottom; the point of the projectile just perforated the back bulge, punching out an attenuated hollow cylindrical section that was driven through the backing and fell in rear of the plate. The surface of the plate was dished ⅝-inch over an area corresponding to a diameter of about 3.5 feet; diameter of flaking, 21 inches; diameter of shot-hole, 13½ inches, the interior being quite rough. The plate showed no signs of cracking. The projectile broke up, some of the pieces getting through, but the bulk falling in front of the plate. This projectile appeared to be of very good quality. It was evident that the plate and projectile were nearly evenly matched, and that with a slightly decreased velocity the projectile would have been defeated. A second round was then fired, using an 850-lb. Wheeler-Sterling projectile, striking velocity, 1769 f. s.; striking energy, 18440 f. s.; location of impact, 3 feet from left edge and 3 feet from the bottom. The projectile smashed on the plate, a portion of the head remaining stuck in the impact. The surface of the plate around the impact was dished and flaked as usual. There were no signs of cracking.

Now, by the formula, the Krupp plate should be perforated by a 12-inch 712.6-lb. projectile with a velocity of 1829 f. s. It with-

stood, however, a velocity of 1993 f. s. The Carnegie plate by the formula should be perforated by a 12-inch 850-lb. projectile with a velocity of 1696 f. s.; it was just defeated by a velocity of 1811 f. s. On the face of it, using the proportion

$$\overline{712}^{\frac{1}{2}}\ (1993-1829)=\overline{850}^{\frac{1}{2}}\ (x-1696),$$

the Carnegie plate, to have been equal to the Krupp plate (the relative quality of the projectiles not being considered), should have defeated an 850-lb. projectile at 1846 f. s. It must be remembered, however, that the angle of impact in the instance of the Krupp plate was 9° from the normal, while in the case of the Carnegie plate the impact was exactly normal; the former plate was slightly cracked after three impacts, while the latter showed no signs of cracking after two rounds. All in all, it may fairly be said that this Carnegie plate is fully as good as that of Krupp.

As to the relative value of the qualities, hardness and toughness, opinions differ. In the development of the art of manufacture of face-hardened armor Krupp seems to have taken the maximum of the latter as the objective point with the greatest amount of hardness consistent therewith; while in this country resistance to penetration has been the prime object. The writer is of the opinion that a degree of hardness could well be sacrificed to increase toughness. The armor makers, however, having reached such a high standard of resistance, are pardonably loath to give up even a modicum of it, and are now striving to increase the toughness and still retain the excellence of resisting power to which they have attained, with encouraging hopes of success, as shown by the experiment described above.

The foregoing remarks apply to the thicker plates; the thinner plates, German and American, seem to possess similar qualities of resistance, both as regards hardness and toughness, with a slight advantage, if any, in favor of the American plates.

The adoption of soft steel caps fitted over the points of projectile has taken away at least 15 per cent from the efficiency of face-hardened armor. The following formula, tentative through lack of sufficient data, especially for the larger calibers of gun and plate, to support its reliability, is proposed for the perforation of face-hardened armor by capped projectiles. The velocities given by this formula agree fairly well with such experiments as

have been made, as will be seen by reference to the appended table.

$$V=\frac{a^{\frac{1}{2}}e^{\frac{4}{5}}}{p^{\frac{1}{2}}}\log^{-1}3.25312$$

Using the same units as before:

VELOCITIES FOR THE PERFORATION OF FACE-HARDENED ARMOR BY CAPPED PROJECTILES.

Gun caliber.	Plate thickness.	Velocity. f. s.
4″	3″	1467
	4	1890
5″	3	1333
	4	1717
	5	2052
	6	2375
	7	2687
8″	7	1520
	8	1691
	9	1858
	10	2022
	11	2182
	12	2339
12″	12	1554
	13	1656
	14	1758
	15	1857
	16	1956
	17	2053
	18	2149
6″	4″	1330
	5	1590
	6	1840
	7	2081
	8	2315
	9	2544
10″	10	1598
	11	1725
	12	1849
	13	1971
	14	2092
	15	2211
13″	13	1515
	14	1608
	15	1699
	16	1789
	17	1878
	18	1966

Following is a table showing thickness of face-hardened armor that would be perforated at different ranges by capped projectiles and projectiles without caps, fired with the velocities given by smokeless powder and striking normally under favorable conditions:

PERFORATION OF FACE-HARDENED ARMOR, WITHOUT BACKING.

Gun Caliber In.	Muzzle			1,000 Yards			1,500 Yards			2,000 Yards			2,500 Yards		
	Muzzle Velocity	Capped Projectile	Uncapped Projectile	Remaining Velocity, f. s.	Capped Projectile	Uncapped Projectile	Remaining Velocity, f. s.	Capped Projectile	Uncapped Projectile	Remaining Velocity, f. s.	Capped Projectile	Uncapped Projectile	Remaining Velocity, f. s.	Capped Projectile	Uncapped Projectile
5	2600	6.7	5.8	2134	5.3	4.4	1934	4.7	3.9	1752	4.1	3.4	1587	3.6	3.0
6	2500	8.9	7.7	2169	7.4	6.3	2020	6.7	5.7	1881	6.1	5.2	1752	5.6	4.7
8	2400	12.3	11.0	2169	11.0	9.7	2063	10.3	9.0	1961	9.6	8.4	1864	9.0	7.9
10	2350	16.1	14.7	2172	14.7	13.2	2088	14.0	12.5	2007	13.3	11.8	1929	12.6	11.2
12	2400	20.7	19.1	2245	19.1	17.4	2171	18.2	16.7	2099	17.5	16.0	2030	16.8	15.3
13	2400	23.1	21.4	2259	21.4	19.8	2191	20.6	19.0	2126	19.8	18.3	2064	19.1	17.6

The tremendous advantages of the higher caliber guns and heavier projectiles is apparent. The sustained velocity and destructive effect due to the weight of the projectile are factors of prime importance. No armor has yet been made that can withstand the terrible blow of a 13-inch shell, fired with a muzzle velocity of 2400 f. s. (which will hereafter be the service velocity, using smokeless powder), and striking normally within a range of 2500 yards. The value of the 8-inch gun may be clearly seen, and arguments for its retention in future battle-ships should be convincing.

The tendency abroad has been to decrease the thickness of armor, the caliber of guns and the weight of projectiles for the different calibers, a curious reaction from the policy in vogue not many years ago when equality between gun and armor was maintained by increasing the power of the former and the thickness of the latter, the quality of both armor and projectile undergoing steady improvement.

The adoption of the face-hardened process almost simultaneously, in this country at least, with the use of nickel in the steel, has resulted to the present time in an increase in efficiency over homogeneous steel armor of 80 per cent for thin plates, 4 or 5 inches in thickness, ranging to about 45 per cent for the very thick plates, and an increased efficiency over oil-tempered nickel steel armor of at least 35 per cent on an average. The advent of the cap has, however, reduced this lead to 20 per cent. The importance of the latter, therefore, must be appreciated, especially as caps can be cheaply fitted to the armor-piercing projectiles now in service.

The logical projectile so far as the power of perforation goes is undoubtedly the solid shot, but its advantage in this regard over shell is more than outweighed by the destructive effect of the latter, due to its breaking up after perforation, especially as armor-piercing shell can now readily be burst after piercing a considerable relative thickness of armor, equal, say, to the caliber of the projectile.

Maker and kind of Metal.	Date of Trial.	Place of Trial.	Dimensions. Length.	Width.	Th'k-ness.	Shape.	Projectile. Cal.	Wt.	Vel.
Carnegie, nickel steel. Mass. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6"	Curved rad., 9' 7"	6"	100	2110
"		"	No. [illegible] without b'k'g.			....	6"	100	2000
"	"	"	"	"	"	....	6"	100	1800
Bethlehem, nickel steel. Mass. [illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	Curved rad., 15' 10"	12"	850	1858
Carnegie, nickel steel. Mass. [illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	" 8' 9'	6"	100	1800
"	[illegible]	"	[illegible]	[illegible]	[illegible]	" "	6"	100	2000
"	"	"	[illegible]	[illegible]	[illegible]	" "	6"	100	2000
"	"	"	[illegible]	[illegible]	[illegible]	" "	6"	100	1800
"	"	"	[illegible]	[illegible]	[illegible]	" "	6"	100	2100
Bethlehem, nickel steel. [illegible]	"	"	[illegible]	[illegible]	[illegible]	" [illegible] 9	8"	250	2004
Carnegie, nickel steel. [illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	" [illegible]	12"	850	1858
Carnegie, nickel steel. [illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	"	12"	850	1858
"	"	"	[illegible]	[illegible]	[illegible]	"	12	850	1858
Carnegie, nickel steel. [illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	Flat.	10	500	1930
"	"	"	[illegible]	[illegible]	[illegible]	"	12	850	1858
"	"	"	"	"	"	"	12	850	1858
"	[illegible]	"	"	"	"	"	12"	850	2037
"	[illegible]		"	"	"	"	12"	850	2000
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	12"	845	1926
[illegible]	[illegible]	"	[illegible]	[illegible]	[illegible]	[illegible]	13'	1100	1810
"	"			"	"	"	13'	1100	1475
"	"			"	"	"	13	1100	1650
[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	13'	1100	1800
					[illegible]	"	13"	1100	1800
[illegible]	[illegible]		[illegible]	[illegible]	"	[illegible]	6"	100	2100
[illegible]					"	"	6"	100	2100
[illegible]	[illegible]				[illegible]	[illegible]	13'	1100	1942
			[illegible]			[illegible]	13"	1100	1942
[illegible]	[illegible]				"	[illegible]	8"	251	1950
			"	[illegible]		[illegible]	8"	251	2080
							8	250	2064
[illegible]	[illegible]			"	"	[illegible]	12"	850	1800
[illegible]	[illegible]					"	13	1100	1800
[illegible]	[illegible]		"			[illegible]	6"	100	2100
							6"	105	2100
							6	105	2100

d kind of :tile.	Penetration.	Effect on Projectile.	Effects on Plates.
er special.	18″ into backing.	Broke up.	Uncracked.
	Through.	"	No cracks, one fragment of shell fell through hole.
	4″ Estimated.	"	One through crack.
	15″ "	"	One fine crack to edge.
	2″.7	"	Uncracked.
	4″	"	"
	4″.5	"	Uncracked, back bulge broken out.
-Sterling	4″	"	Uncracked.
-Sterling	Through.	"	Old cracks opened.
mond.	2″ into backing.	"	Cracked into four pieces.
r-Sterling.	Through all.	Point abraded.	Uncracked.
"	9″.5	Broke up.	Cracked through from each impact to upper edge.
er.	9″.5	"	Cracked through horizontally from No. 1 to lower edge.
	9″.5 Estimated.	Head held in plate, remainder rebounded in fragments.	Flaked to diam. 24″.
:-Sterling.	Through plate and backing.	Recovered whole, 1″ of point gone.	Slight flaking, hole smooth.
er.	" " "	Broke up.	Diam. of hole 14″.5, plate cracked from top to bottom.
:-Sterling.	" " "	"	Shot hole clear and smooth.
"	" " "	"	Cracked through.
.solid steel, ap.	9″ Estimated.	Broke up, head of shot fused and imbedded in shot hole.	Through cracks to top of impact, Nos. 1 and 2.
er.	Through plate and backing.	Recovered entire.	Dished 2″, cracked through.
	9″ Estimated.	Broke up into large number of pieces, head welded in hole.	Left end broke off, cracked, splashed and flaked.
	8″ "	Broke up.	Left hand upper portion broken away, through cracks.
	Through plate and backing.	Fragments lodged in sand butt.	Cracked from top to bottom.
	" " "	" " "	
r-Sterling.	Point just through.	Broke up.	Uncracked.
er.	4″ Estimated.	Broke up into small pieces, head remained in plate.	Through crack to impact No. 1. Back bulge broken out and smashed into sand butt.
r-Sterling.	10″ to 12″	Broke up, all pieces passing through backing, recovered in sand butt.	Probably gave way before penetration was complete, right hand portion of plate and backing completely wrecked, all armor bolts displaced.
r-Sterling, shell.	7″ Estimated.	Broke up in small pieces, welded in hole.	This fragment broke into four pieces, separated from backing, and thrown to ground.
.	6″.5 "	Broke up, head fused into impact.	Right hand plate flaked and dished, cracked from impact to top.
r-Sterling.	7″.25 "	Broke up into small pieces, head welded into impact.	Through crack to left edge, flaked.
ter.	7″.25 "	Broke up, head welded into plate.	Left hand plate, through crack to bottom.
r-Sterling.	17″ Point through plate.	Broke up below bourrelet.	Through cracked from top to bottom through impact, other cracks not through.
"	Through plate and backing.	Point fused, but projectile otherwise entire.	Uncracked.
"	3″.75	Broke up, head welded in plate.	Through crack in left side of plate, splashed and flaked.
solid steel, ap.	4″.5 Estimated.	" " "	Practically same effect as in previous round.
"	5¾″	" " "	Further through cracks, flaked.

Maker and kind of Metal.	Date of Trial.	Place of Trial.	Dimensions.			Shape.	Projectil	
			Length.	Width.	Th'k-ness.		Cal.	Wt.
Carnegie, nickel steel. Reforged (for Russian Govt.) R. 12	Mar. 26, '96.	Indian Head.	12' 9"	8' 7"	5"	Warped.	5"	50
Carnegie, nickel steel. Reforged (for Russian Govt.) representing lot 2. R. 44...	May 16, '96.	"	12' 9"	8' 7"	8" top to 4" bot.	Warped.	6"	100
Carnegie, nickel steel. Reforged (B. 122½).........	May 27, '96.	"	17'	5' 6"	8"	Flat rectangular. (Unbacked.)	8"	250
" "	"	"	"	"	8"	"	8"	250
" "	"	"	"	"	8"	"	8'	250
" "	May 29, '96.	"	"	"	8"	"	8"	250
" "	"	"	"	"	8"	"	8"	250
Carnegie, nickel steel.........	June 4, '96.	"	17' 1"	3' 9"	13"	Unbacked. Flat rectangular.	12"	851
" "	June 17, '96.	"	17' 1"	3' 9"	13"	"	12"	848
" "	"	"	17' 1"	3' 9"	13"	"	12"	844½
Carnegie, nickel steel. Face-hardened, reforged, B. 122½......................	"	"	17'	5' 6"	8"	Flat rect.	8"	250
Carnegie, nickel steel...	....	....	17'	5' 6"	8"	"	8"	251
							8"	251
Carnegie, nickel steel.........	July 1, '96.	"	16' 8"	5' 5".5	8"	Unbacked. Flat rectangular.	8"	252
" "	July 17, '96.	"	16' 8"	5' 5".5	8"	"	8"	252
" "	"	"	16' 8"	5' 5".5	8"	"	8"	251
" "	"	"	16' 8"	5' 5".5	8"	"	8"	260
" "	"	"	16' 8"	5' 5".5	8"	"	8"	250
" "	Aug. 19, '96.	"	Frag	ment of	above.	"	8"	250
" "	Oct. 8, '96.	"	"	"	"	"	8"	250
" "	Aug. 21, '96.	"	17'	8'	13"	"	12"	850
" "	"	"	"	"	13"	"	12"	850
Bethlehem, nickel steel.	Sept. 18, '96.	"	16'	7' 6"	12"	Flat, tapered.	12"	850
(Texas side)...........	"	"	"	"	12"	"	12"	850
" "	Oct. 21, '96.	"	"	"	12"	"	12"	850
Carnegie, nickel steel....	Sept. 15, '96.	"	Frag	ment	8"	Flat rectangular.	8"	250
" "	Oct. 30, '96.	"	.. ....	....	12"	Unbacked.	12"	850
" "	Nov. 10, '96.	"	....	... .	12"	"	12"	850
" "	Nov. 17, '96.	"	Frag	ment	12"	"	12"	850
" "	Nov. 12, '96.	"	"	"	12"	"	12"	852
" "	Nov. 23, '96.	"	"	"	8"	"	8"	850
Carnegie, nickel steel. (B. 491 Kentucky's barbettes)	Dec. 29, '96.	"	8' 2"	12' 10"	12".5	Curved.	12"	850
Carnegie, nickel steel. (B. 480, Kearsarge for'd side)	Feb. 12, '97.	"	21' 4"	7' 6"	4"	Flat.	5"	50
Bethlehem, nickel steel. (8337 B, conning tower shield, Kentucky)	May 8, '97.	Redington.	11' 5"	5' 7"	10"	Curved.	8"	250
Carnegie, nickel steel. Experimental.........	May 29, '97.	Indian Head.	12'	8'	12"	Flat.	12"	850
"	"	"	"	"	"	"	"	850

...d kind of ...ctile.	Penetration.	Effect on Projectile.	Effects on Plates.
-Sterling.	2"	Broke up, point welded in impact.	Small crack in back bulge, the triangular piece in upper right hand corner 16"x 10" broke off, splashed and flaked.
· A. P.	7"	Broke up, point and portion of bourrelet welded in impact.	Plate uncracked.
r A. P. No. ptance test ting lot 1).	3".5	Broke up on plate, portions of head and point welded in impact, shell reduced to small pieces, almost the entire shell being broken up completely.	Plate dished .50" at impact, no cracks.
e A. P. Ex- tal No. 248.	7"	Portion of head welded into impact, remaining portion rebounded, cracked from base to bourrelet through middle.	Diam. of hole 8".5. Diam. of splash and flaking 15". Back bulge 4" high, 15" diam. Plate through cracked from impact to right edge. A surface crack developed, extending 24" to left and above impact.
le A. P. Ex- tal No. 333.	8".5	Rebounded to front, shortened 6".5 and upset to a diam. of 8".75 at bourrelet, body normal 7" from base, point gone, with head fused and scarred.	Diam. of hole 8". Depth 9". Diam. of splash and flaking 16". Back bulge 3".5 high, broken out to a diam of 9". Diam. of back bulge 21".
ater A. P. No. ceptance test ating lot 13).	4"	Broke up, head to for'd edge of bourrelet welded into impact, body of shell broken into ten pieces.	Dished 1" at impact and over 48" diam. Back bulge 2".25 high. Surface cracks.
nter A. P.	Through plate.	Broke up.	
ler-Sterling	"	Broke up into 72 pieces.	Back bulge broken out cone shaped, upper right hand corner broken off.
ler-Sterling	"	Practically uninjured.	Right hand lower corner broken off, horizontal through cracks.
nter.	"	Broke into 33 pieces.	Right hand portion broken off.
enter A. P.), 3d accept-	6"	Broke up on impact, 21 pieces recovered, head welded in impact.	Two through cracks through old impact.
ler A. P. (Lot acceptance.	8"	Broke up, point welded into impact, 23 pieces recovered.	Through cracks to No. 7.
"	7"	Broke up, point welded into impact, 15 pieces recovered.	Through cracks vertically from top to No. 17, thence to No. 10.
ler-Sterling.	Through plate.	Uncracked, 1".39 point gone.	No cracks.
"	"	Uncracked, base broke off.	"
ler-Sterling	"	Went through.	"
ler-Sterling mental.	"	Penetrated plate and broke up.	Back bulge 17" broken out all around.
ler-Sterling mental A. P.	"	Broke up, 49 pieces recovered.	Plate badly cracked.
nter.	"	Projectile cracked but not broke up.	Right hand portion detached.
·	"	Broke into 26 pieces.	
ler A. P.	"	Broke into large number of pieces.	Plate through cracked, 2 fragments detached.
"	"	Recovered entire.	Plate completely demolished, fragments scattered.
"	"	" "	Through cracked, corner detached.
"	"	Recovered, broken into 6 pieces.	Through cracked, pieces detached.
nter.	"	Broken into 34 pieces.	Plate cracked, right hand portion wrecked.
	"	" " 15 "	Usual flaking, and back bulge broken out.
ler.	Through except 6 sm. pieces.	Broken into large number of pieces.	Fragment broken off corner, cracked.
nter.	" " 6 "	" " " "	Through cracked, pieces detached.
'	Through.	" " " "	Plate completely wrecked.
ler.	"	" " " "	Fragment completely wrecked.
enter.	"	Broken into 127 pieces, all through.	No cracks.
enter.	10".5	Smashed, fragments remaining in front of plate.	Back bulge broken out in cone shaped mass, and driven into target structure. Plate broken into 3 pieces.
· This shot was rify the velocity e formula, which	Point just through.	Broke up, half its length fell in front of plate, head broke through plate and buried itself in the backing.	Uncracked. Back bulge broken out in shape of obtuse cone, having base 24" in diameter, and lodged in backing.
ter.	10"	Broke up, head striking in plate.	Uncracked, usual flaking, dished ⅛".
ter.	Through.	Broke up, small pieces getting through, major portion remaining in front of plate.	Uncracked. Dished ¼". Back bulge broken out in form of cyl. section, and driven into and through backing.
ler-Sterling.	Unknown.	Uncracked, fragment remaining in front of plate.	Uncracked.

DATE OF TRIAL.	CHARACTER OF PLATE.	PREVIOUS IMPACTS.
1894 March 12.....	Carnegie, nickel steel, Harveyized. 8'x6' 2"x12" flat. Backing 2' Oak.	
April 12......	Carnegie, nickel steel (Brooklyn's side), 13'x8'6"x3". Backing 24" thick.	3 impacts with Carpenter 4" A. P. projectile at velocities of 1 and 1800 f. s., respectively, failed to perforate. Plate uncrack
July 12.......	Carnegie, nickel steel, Harveyized. 13' 1" x 8' 8" x 17" Curved rad. 15' 10". Backing 3' Oak.	(1.) Carpenter 12" A. P. shell at 1410 f. s., penetrated 15" and re whole, no cracks in plate. (2.) Wheeler-Sterling 12" A. P. shell at 1858 f. s., went through backing, whole, no cracks in plate. (3.) Carpenter 12" A. P. shell at 1858 f. s., broke up after penetra one through crack in plate. (4.) Carpenter 12" A. P. shell at 1858 f. s., broke up after penetra former cracks opened up. (5.) Midvale 10" A. P. shell at 1983 f. s., rebounded whole, but ably set up, penetration 20", several new cracks in plate. (6.) Midvale 10" A. P. shell at 1983 f. s., rebounded, much set up torted, penetration 12" .5, another through crack in plate.
July 20.......	Bethlehem, nickel steel, Harveyized. 16' 7" .5x7' 6"x18" flat. Thickness uniform over 4' of width, then tapering to 8" at bottom. Backing 3' Oak.	(1.) Carpenter 12" A. P. shell at 1465 f. s., broke up, penetration cracks in plate. (2.) Carpenter 12" A. P. shell at 1926 f. s., broke up, penetration through crack. (3.) Wheeler-Sterling 12" A. P. shell at 1926 f. s., broke up, pe 15", additional cracks.
Oct. 2........	Carnegie, nickel steel. Mass. 8" B. L. R., barbette. 21' 8"x 5' 3½"x6". Curved, unbacked.	8 impacts at various velocities with Carpenter and W. S. 6" pro no perforations.
1895 Feb. 12 . . .	Carnegie, nickel steel, Harveyized, reforged. 17' 6"x4' 8"x7" curved. Backed by 24" Oak.	(1.) Carpenter A. P. shell at 1620 f. s., smashed on plate, penetra plate uncracked. (2.) Wheeler-Sterling A. P. shell at 1816 f. s., smashed on plate, tion 3", plate uncracked.
April 27.....	Carnegie, nickel steel, Harveyized, reforged. 17' 3"x4' 8"x6" flat. Unbacked.	(1.) Wheeler-Sterling 6" A. P. shell at 2100 f. s., broke up, poi set up and fused, point just through plate. (2.) Carpenter 6" A. P. shell at 2100 f. s., broke up, head rema plate, penetration about 4".
May 5	Carnegie, nickel steel, Harveyized, reforged. 8'x6'x10" flat. Backed with 12" Oak and 3 mild steel plates, ½" thick.	8" Carpenter A. P. shell at 2064 f. s., projectile smashed, plate from impact to top.
1896 March 11.....	Carnegie, nickel steel Exp. Backed with 12" Oak. 11' 2"x8' 7". Thickness 5" at bottom, tapering to 3.5" at top.	8 impacts with Carpenter and W. S. 4" projectiles. Slight cracks developed but plate otherwise uninjured.
May 5	Carnegie, nickel steel, Harveyized, reforged. 17' 6"x4' 8"x7" curved. Backed with 12" Oak.	
May 9	Bethlehem, nickel steel, Harveyized. 13' 3" .5x5' 9" .5x15". Curved to a rad. of 14' 4". Backed by 8" Oak and 2 ½" mild steel plates.	(1.) Carpenter 10" A. P. shell at 1539 f. s., smashed, penetratic cracks in plate. (2.) Carpenter 10" A. P. shell at 1940 f. s., smashed, penetratio cracks. (4.) 12" W.-S. shell at 1701 f. s. Penetrated 11".5 and broke up. crack from impact No. 3 to bottom of plate.

JECTILE.	STRIKING VELOCITY.	RESULT.
" shot, soft steel ht 500 lbs.	1600 f. s.	Projectile broke up, penetration 9", plate wrecked.
erling shell, fitted ison soft steel cap.	1700 . s.	Perforated; broke up; no cracks.
" shot, soft steel ht 500 lbs.	1983 f. s.	Projectile penetration 20", and remained sticking in plate with base broken off, very little distortion, cracks in plate opened up further.
" shot, soft steel ht 500 lbs.	1983 f. s.	Projectile rebounded, broken into five large pieces, very little distortion, penetration 15" .6, broke fragment out of plate.
shell, fitted with cap.	1900 f. s.	Perforated; projectile whole; plate uncracked.
shell, fitted with cap.	1700 f. s.	Perforated; projectile whole; plate uncracked.
shot, soft steel cap, 00 lbs.	2100 f. s.	Projectile went through plate and backing, and was found in butt with point broken off, but otherwise uninjured, plate uncracked, hole through plate smooth.
shot, with soft steel ght 100 lbs.	2100 f. s.	Projectile went through plate and backing, and was found in butt with head broken off, but otherwise uninjured, hole through plate smooth.
shot, soft steel cap, 00 lbs.	858 f. s.	Projectile smashed on plate, practically no penetration.
shot, soft steel cap, 00 lbs.	2100 f. s.	Projectile went through plate, 24" oak and 8' of earth, and was found entire, uncracked and very little upset.
shot, soft steel cap, 00 lbs.	2100 f. s.	Projectile went through plate, 24" oak, 9' of earth, and was found entire and uncracked, except flaked off at base.
shot, soft steel cap, 00 lbs.	2100 f. s.	Projectile went through plate, 24" oak and 10' of earth, and was found very little upset and uncracked, but with a transverse fracture through band score.
shot, soft steel cap, 00 lbs.	2100 f. s.	Projectile went through plate, 24" oak and 10' of earth, and was found entire, uncracked and practically undistorted.
shot, soft iron cap, 00 lbs.	2100 f. s.	Projectile penetrated 7" into plate and broke off transversely at bourrelet, the ogival remaining imbedded in plate in one piece, and the rear body rebounding. The diameter of rear body was increased 6" .11, but otherwise the projectile seemed undistorted. Old cracks in plate opened somewhat.
shot, soft steel cap, 00 lbs.	2505 f. s.	Projectile went through plate and backing, and was found 8' in sand, but entire, except that half of base was broken off diagonally to the band score. Two small longitudinal surface cracks on body, diameter increased to 6" .11 and length increased 0" .49, hole through plate 6⅝" diameter, and mostly smooth, no further cracks in plate.
shell fitted with cap.	1711 f. s.	Perforated; lodged in backing, breaking up. Plate not cracked.
shot, soft steel cap, 00 lbs.	2100 f. s.	Line of fire 21° from normal to plate, projectile broke up after penetrating 5", the pieces rebounding, no projectile metal adhered to impact, back bulge broken out from plate and forced into the backing, plate cracked through impact.
" shot, Aluminun p, weight 100 lbs.	2100 f. s.	Normal impact, projectile went through plate, backing, target structure, and was found 8" in butt, entire, and but slightly distorted, hole through plate smooth, plate badly cracked.
" shot, soft steel ght 850 lbs.	2000 f. s.	Line of fire 21° from normal, projectile went through plate and backing, breaking up into large pieces, hole through plate 12¾" diameter, and fairly smooth, plate badly cracked.
2" A. P. shell, fitted nson cap.	2000 f. s.	Perforated plate and broke up. Through cracks developed.

DATE OF TRIAL.	CHARACTER OF PLATE.	PREVIOUS IMPACTS.
1897		
Jan. 8........	Carnegie, nickel steel. Harveyized, reforged. 22′ 8′ x 8′ x 6″ flat. Unbacked.	(1.) Carpenter 6″ A. P. shell at 2122 f. s., went through plate, l up into small pieces. (2.) Carpenter 6″ A. P. shell at 2050 f. s., broke up, all pieces, large piece of base going through plate. (3.) Carpenter 6″ A. P. shell at 1957 f. s., smashed on plate, hea into impact, no cracks in plate. (5.) Carpenter 6″ A. P. shell, fitted with *thin* hollow cylindrica cap, filled with graphite lubricant, striking vel. 1986 f. s., broke remaining sticking in plate.
Jan. 20.......	Carnegie, nickel steel. Harveyized, reforged. Same plate as fired at Jan. 8th, 1897. 6″ thick. Unbacked.	(6.) Wheeler-Sterling 6″ A. P. shell, diagonal, smeared with lubri 1986 f. s., broke up, head remaining sticking in plate. (7.) Carpenter service 6″ A. P. shell, cavity filled by steel plug, ting a solid shot, at 1986 f. s., smashed on plate. (8.) Carpenter 6″ A. P. shell, fitted with cap similar to that used 5, except that the walls of cap were ¼″ thick instead of 1/16″, vel. 1957, broke up, 25 pieces recovered, all going through plate. (9.) Carpenter 6″ A. P. shell, fitted with cap precisely similar to t in round 8, striking velocity 1825 f. s., smashed on plate, penetrati (11.) Carpenter 6″ A. P. with hollow cylindrical copper cap ⅜′ filled with graphite lubricant, striking velocity 1796 f. s., pe plate, making smooth hole, and broke up, all parts going throug (12.) Carpenter 6″ A. P., fitted precisely as in round 11, striking 1821 f. s., perforated plate and broke up into large numbers of Fractures seemed to indicate an inferior projectile. (13.) Carpenter 6″ A. P. without cap, at 1859 f. s., smashed, head in plate. (16.) Carpenter 6″ A. P., fitted with solid copper cap, coating of between projectile and cap, striking vel. 1807 f. s., smashed o disintegrating in an unusual way. Fractures indicate a proje very poor quality. (17.) Carpenter 6″ A. P., fitted with hollow steel cylindrical cap and 3¼″ inches high, at 1784 f. s., perforated plate, breaking u dently a good quality of shell.

JECTILE.	STRIKING VELOCITY.	RESULT.
' A. P. shell, fitted son soft steel cap, lbs.	1986 f. s.	Projectile went through plate, making a smooth hole 6″ in diameter, and was found in butt broken into large pieces.
iter 6″ A. P. shell, Johnson soft steel it 100 lbs.	1825 f. s.	Projectile went through plate, making a smooth hole 6″ in diameter, and was found in butt broken into large pieces.
iter 6″ A. P. shell, Johnson soft steel ithout lubricant.	1813 f. s.	Projectile smashed on plate, head remaining in hole, penetration about 6″
iter 6″ A. P. shell, Johnson soft steel ithout lubricant.	1821 f. s.	Projectile broke up, about half going through plate, hole rough and 7″ in diameter.
ater 6″ A. P. shell, Johnson cap.	1785 f. s.	Perforated plate and broke up, 30 pieces recovered, largest weighing 23 lbs., and the whole 70 lbs. Projectile was of excellent quality.
iter 6″ A. P. shell, h Johnson cap.	1793 f. s.	Perforated plate and broke up, four pieces recovered weighing 91 lbs., of which the largest weighed 63 lbs. Projectile was of excellent quality.

IOTE.—This plate appears to have been one of unusually good quality from the erity of the tests to which it was subjected, cracking and breaking as it did only en the impacts formed a network of holes close together. It appears, however, have been somewhat weakened by the great number of impacts, as the later unds seem to show.

Results of Recent Experiments with Krupp Face-Hardened Armor.

Impact.	Gun. Cal.	Projectile.	Weight. lbs.	Striking Velocity (f. s.) Actual.	Striking Velocity (f. s.) From Formula.	Striking Velocity (f. s.) By "Krupp" Formula.	Energy. ft. tons.	Effect on Projectile.	Effect on Plate.
					Krupp, 5″ .75. Hardened nickel steel. Plate No. 41311. December, 1894.				
5	8″ .3	Krupp	209.4	1643.4	1637	1719	3920.8	Broke up, one part found in front of plate, point and remaining fragments lodged in backing.	Previously attacked by three 5″ .9 projectiles and one 8″ .3 projectile, none penetrated, 3 surface cracks.
	Krupp, 5″ .75 hardened nickel steel. Plate No. 425 B. December, 1894. Previously attacked by two 5″ .9 Krupp A. P. projectiles. No penetration or cracks.								
3	8″ .3	Krupp	211.	1561.7	1630	1712		Broke up.	Plate not perforated.
4	8″ .3	"	210.5	1627.	1630	1712	3862.	Broke up, number of pieces through.	Plate stamped through.
5	5″ .9	"	112.4	2021.	1884	1981		Broke up, pieces lodged in backing.	Plate stamped through, part of back bulge broken out.
					Krupp, 10c/m (3″ .9), face-hardened nickel steel. Plate No. 475. Previously received 6 impacts with 4″ .1 and 5″ .9 projectiles. March, 1895.				
7	5″ .9	Krupp	112.4	1341.9	1407	1342	1403.1	Broke up, fragments of projectile in shot hole weighing 100.3 lbs.	Perforated, section punched out.
	It is interesting to note that a 5″ .9 Krupp common shell with bursting charge of 25.4 lbs. was fired at this plate at a velocity of 2107.7 f. s.; the shell exploded, the plate was perforated and a section broken out, fragments of punched out section passed into backing, and back of plate broken out to a diameter of 30″.								
8	4″ .1	Krupp	35.3	2067.3	2094	1996	2094.	Broke up into small fragments.	Section punched out.
					Krupp 3″ .1 face-hardened nickel steel. Plate No. 476 A. October, 1895. Backed. Previously attacked by 2-3″ .5 and 2-4″ projectiles, no penetration, slight surface cracks.				
5	5″ .9	Krupp	88.2	1333.7	1276	1207	1087.2	Broke up, fragments perforating plate and passing through backing.	Perforated plate and backing, section of surface of plate about point of impact driven into backing.
6	4″ .1	"	35.3	1775.3	1762	1586	842.6	Broke up, fragments in front and rear of plate.	Projectile perforated plate and punched out section, which was driven into backing.

... No. 470 B. October 1895.

Previously attacked by 3 3″.5 shells—not perforated or cracked.

4	4″.1	Krupp	35.3	1376.	1762	1586	463.4	Broke up, point got through, remainder rebounded.	Perforated, punched out section which passed into backing.

This shell is believed to be of extraordinary quality, and at the same time the plate appeared to be inferior to No. 475 A which resisted the attack of two 4″.1 shells fired with velocities 1412.1 and 1522.7 respectively.

Krupp, $350^{m}/_{m}$ (13″.78) hardened nickel steel. Plate No. 575 A.
Tested at Meppen, August, 1896. Backed with $60^{m}/_{m}$ oak.

1	12″	St. Chamond	717.29	2116.5	2048	2676	22269.5	Broke up, 2 large fragments found in front of plate.	Hair cracked, ogival penetrated plate and pushed out section which lodged in backing.
2	12″	St. Chamond	718.6	2119.8	2047	2674	22376.0	Sticking in plate, body split lengthwise.	Back bulge opened to a width of $80^{m}/_{m}$, hair cracks.
3	12″	St. Chamond	715.6	2103.6	2050	2679	21940.4	Broke up, ogival welded in section, punched out, fragments found in front of plate.	Section pushed out and lodged in backing, further hair cracks developed.

Krupp, $368^{m}/_{m}$ (14″.49) hardened nickel steel plate. No. 619.
Meppen, August 28th, 1896.

1	12″	St. Chamond	715.6	2159.	2127	2818	23115.	Broke up, mushroom welded into section of plate punched out, fragments found in front of plate.	Projectile punched out section, surface cracks developed.
2	12″	St. Chamond	715.7	2157.	2127	2818	23086.	Broke up, mushroom welded into section of plate punched out, fragments found in front of plate.	Projectile punched out section, surface cracks developed.
3		Krupp	718.1	2152.	2125	2815		Broke up, head stuck in plate.	Section of plate pushed out, fine cracks.

Krupp $300^{m}/_{m}$ (11″.8) hardened nickel steel plate.
September 15, 1895.

2	12″	Krupp.	715.4	1889.	1825	2321	17690.	Broke up; head sticking in plate, fell off at next round. Penetration 7″.	No cracks.
3	12″	"	712 6	1993.	1829	2326	19614.	Broke up head.	Three surface cracks developed, the greatest depth being 3″.5. Back bulge, 3″ high, containing small crack 5″.9 in length.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

MILITARY TRAINING.*

By Henry G. Beyer, Surgeon, U. S. Navy.

Gentlemen:—The training of the soldier, though in actual practice not a part of the duty of the medical officer, must nevertheless be considered a problem in practical physiology and hygiene, and as such it justly excites both our interest and sympathy.

The same training exactly that applies to the soldier may, with but little modification, be applied to the man-of-war's man, for, say what we will, since masts and sails on board a man-of-war have been altogether displaced by engines and steam, since the sailor can no longer go over the masthead for his morning and evening constitutional, and work on the sails, he has become more of a soldier than he was, and consequently needs more of a soldier's training than he did in former times.

By military training, therefore, I would have you understand not only the application of certain gymnastic exercises, intended to develop the physique of the soldier in certain spots, but the term, as here used, implies a study of the influence which a soldier's occupation, with all its many accompaniments, has on the man as well.

From such a study we will find that the ideal, properly brought up and finished soldier is an athlete in the modern sense, and one who has no superior in the field or out of it.

We will, I hope, come to the further conclusion that the soldier has not only but little to learn from a sport like foot-ball, but that unless, indeed, every man in the ranks as well as every officer

* Written for the Association of Military Surgeons of the United States.

be taught to play it, it would even prove a direct disadvantage when considered seriously.

The most senseless statements have been made in the most rambling sort of fashion as regards the wonderful influence of foot-ball and other athletic sports on the soldier, as if it was the universal panacea and *sine quâ non* for all military purposes. I am, on the contrary, of the opinion that the soldier *per se* has nothing whatever to learn from, for instance, foot-ball discipline, but should rather say, if there must be discipline in foot-ball training, it simply is military discipline applied to an athletic sport, and whoever advocates foot-ball training as being an aid to *military* discipline puts the cart before the horse, and can have very little idea of what discipline really is and where it originated.

As regards the amount and kind of strength and endurance to be derived from foot-ball training, though very great and most satisfactory for a sportsman, these do not come up to the amount and kind of strength and endurance now-a-days required of the finished soldier.

If we could ascertain and express in foot-pounds the amount of work done in a given time by the soldier in the field during, say, an autumn-maneuver, as easily as we can count the number of bacteria in a given quantity of water, and compare this to the amount of work done by any other athlete or strong man for the same length of time, we would find the soldier far ahead and in better condition at the end of it than is either the sportsman, athlete or strong man.

Foot-ball is, after all, mere play, and should never be regarded as anything else. A soldier's calling is and must be of a more serious nature, having a more serious object, and kindergarten methods do not apply to such training, at such an age and for such a purpose. It is merely a fine pastime and recreation.

My ideal soldier would be the one whom we find represented by the infantryman of the best European armies, and the conditions and requirements peculiar to and unavoidable in the United States, when compared to those of Europe, no matter how different they may be, can have no essential modifying influence upon our conception of what the soldier ought to be and what our aim should be with regard to his training.

In writing this paper, and before proceeding with the subject

with which I have been charged by your literary committee, I must acknowledge my indebtedness to Dr. Leitenstorfer, to whose valuable monograph* I owe much of what I have to say on Military Training in the pages that follow.

One of the fundamental conditions for the successful training of the soldier being the harmonious co-operation of the training officer and the military surgeon, we must begin by studying the nature of this bond which so closely unites both their interest and responsibility in this work.

The human body has been spoken of as a workshop in which every organ and cell performs its special duty assigned to it, in its proper time and place, and for the common good of the whole.

But work, in the mechanical sense, is done by muscle and muscular organs alone. Since all training, as applied to the human subject, has for its object and purpose the increase of man's capacity for work, it is with muscle more especially that the physical trainer has to deal. A knowledge, on the part of the trainer, of the physiology of muscle must, therefore, be considered the *conditio sine quâ non* of all successful training.

Let us, therefore, briefly review the most essential points in the physiology of muscle and of those other organs and tissues upon the functions of which muscular work most directly depends.

Muscle.—By far the most distinctive and important property possessed by muscle is its *contractility*. All the tissues, even bone, possess a certain amount of elasticity, but muscle alone is *contractile*. The biceps muscle, in contracting or shortening, flexes the forearm upon the arm. In so doing that muscle performs a certain definite and measurable quantity of work. When a long muscle is made to contract as much as it can, it loses about half its length, but gains in circumference and hardness what it has lost in length. A muscle never contracts without a stimulus. Of the various stimuli to which muscle answers by a contraction, the only one that can interest us here is the stimulus transmitted to the muscle through its motor-nerve and coming directly from the brain.

Voluntary or skeletal muscles are under the direct control of our will, and can be made to contract, therefore, by an effort

* Das Militärische Training, etc., von Dr. Leitenstorfer, Oberstabsarzt 1. Klasse u. Regimentsarzt im K. B. Infanterie-Regiment König Wilhelm von Würtemberg. Stuttgart, 1897.

of that will as much and as often as we desire, while *in*voluntary muscles, not being under the control of the will, contract in spite of our will.

The trainer, therefore, addresses his efforts to the voluntary or skeletal group of muscles only, or those that are attached to and move the skeleton.

As soon as the stimulus conveyed to the muscle from the brain ceases, the contracted muscle returns to its normal resting length. In case it is desirable to keep a muscle in a state of contraction for some time, a series of very quick impulses becomes necessary. Stimuli are then sent into the muscle in quick succession, but none is as strong as the first, and by-and-by they become weaker until they cease entirely.

The trembling which we notice about the entire limb during this tonic contraction of its muscles is simply due to the various stimuli running in quick succession through the nerves into the muscles attached to it, and does not necessarily mean the fatigue of the limb.

Muscle possesses a certain property known as tonus or tension. This tonus denotes a condition of constant readiness for making a contraction. The tonus of a muscle is not yet work, but is rather a preparatory stage of it, and passes into actual work imperceptibly.

Co-ordination is the harmonious working together of all or certain groups of muscles, while muscle-sense is that property of muscle which has been acquired by experience and developed by practice, and by means of which the muscle estimates, as it were, the amount of pressure of any weight or resistance that rests upon it; this sense is more particularly developed in balancing exercises. Persons with locomotor ataxia have no muscle-sense, and consequently are unable to balance themselves with their eyes shut.

The chemical process which accompanies muscular contraction consists in the oxidation of certain definite quantities of carbo-hydrates and fats into carbon-dioxide, accompanied by the production of heat. Under ordinary circumstances the muscular substance remains intact and only loses part of what it had stored up in fats and carbo-hydrates, and which it had taken from the blood during its resting stage. "*The muscle cannot nourish itself during contraction.*" If we were capable of replacing these

substances as fast as they are used up, no fatigue would be possible, since, however such substances can only be appropriated by the muscle during the periods of rest, they are exhaustible through continued work.

It is the same with the products of wear and waste; these also require a condition of rest to be thoroughly removed, and their presence alone in the muscle would be sufficient to put a stop to its work.

The circulation of the blood is charged with the two-fold office of supplying new material, as well as with that of removing the old and used-up substances. Hence the increased circulation in every working muscle and the reflex dilatation of its blood-vessels. For the reason that, in a strongly contracted muscle, the blood-flow through it is impeded on account of its blood-vessels being compressed, it follows that a continuous contraction is much more quickly fatiguing to a muscle than are contractions alternating with periods of rest, no matter how short. When in a state of fatigue the muscle possesses less tone and elasticity, and is therefore much more easily overstretched than normally. This condition is particularly to be dreaded on account of its serious and, most likely, permanent consequences when affecting the muscular substance of the heart.

For the reason that muscle can be nourished only during rest, the oftener a muscle is fatigued by work and allowed to rest for the sake of recuperation, the more often also recur these periods of nourishment, and muscle grows in consequence. Overdoing, however, produces swelling, heat, pain, inability to contract, and delay in normal recovery, on account of the normal conditions being seriously interfered with. As the muscle grows in extent, its capacity for storing up energy also becomes enlarged. Hypertrophy of muscle can only be applied to that condition in which the normal bilateral symmetry is destroyed—by one side of the body showing much more muscular development that the other. This condition may prove a source of weakness rather than of strength, and should, therefore, be guarded against. A steady and uniform increase in the size and strength of all the muscles at the expense of useless fatty tissue is the ideal which we wish to attain.

Lungs.—It cannot be doubted that, of all the organs that are concerned in training, outside of muscle itself, by far the greatest

and heaviest requirements are put on heart and lungs. It is these two organs, therefore, that also require to be watched with the greatest care in individual cases, since no previous physical examination can be considered an absolute guarantee in all cases that they will stand the pressure of training. Extreme pallor, with an abnormal pulse during muscular efforts, should meet with early and careful attention.

When we consider that the function of the lung consists on the one hand in removing carbon-dioxide from the blood, and on the other in supplying oxygen to it, it ought to be perfectly clear that breathing must become more rapid in mounting a flight of stairs than it is while lying down. The explanation is a, comparatively speaking, simple one: The muscles of the legs have performed a large amount of work in raising the weight of the body to a height of from 15 to 25 feet in a short space of time. In overcoming so large an amount of resistance the muscles concerned in the task had to use up a certain quantity of fats and carbohydrates producing carbon-dioxide, and needing for this purpose an increased amount of oxygen. This increased exchange of oxygen for carbon-dioxide must be effected through the lungs, and hence their greater activity during exercise.

The retention of carbon-dioxide in the blood would result in the quick suffocation of the muscle and end its work.

In a person, while at rest, the number of respirations is sixteen in a minute; during sleep it may be still less; during work it may be from twenty to thirty; under hard work, as mountain-climbing, running, dancing, it may be increased to forty to sixty per minute; while during racing it may be increased to the extraordinary number of 100 to 140. But such frequency in the number of respirations would indicate respiratory insufficiency; frequency increased at the expense of thoroughness.

The following table, taken from Leitenstorfer, shows the approximate amounts of CO_2 exhaled:

	CO_2 P.M.	No. Resp.	Pulse.
Sleeping	0.38	10–12	60–70
Lying down	0.57	16	75
Walking	1.42	20	80
Walking fast	2.03	26	100
Climbing	3.38	30–60	120–160
Maximal Work	....	100–140	200–240

While, in climbing, the amount of CO_2 exhaled is ten times that while sleeping, we ought also to breathe ten times more rapidly than we do while sleeping, which would make $10 \times 12 = 120$ times.

But breathing while sleeping is very superficial, which is, of course, not the case during a steep climb, when our whole lung area is engaged in the exchange of gases. We experience, as the effects of training, especially of running, an enlargement of our lung capacity, which normally varies from three to six liters.

Heart.—The relation of the heart to muscular work is similar to that which the lung has; it also must answer to an increased demand for work by more numerous and more voluminous contractions than it makes during rest, for much more blood flows through the muscles in a given time. To this must be added the increased resistance which the contracted muscles oppose to the flow of blood through them, resulting in an increased general blood-pressure, which the heart must sustain. The greater the muscles and the larger their number engaged, the greater also must be the resistance opposed to the blood-flow, and the greater, consequently, the increase in blood-pressure to be overcome.

While respiration is aided by the muscles of respiration which are skeletal muscles, and under the control of the will, the muscular action of the heart is perfectly independent of our will. In the main, however, both the heart and the lungs in their action are governed primarily by the want and the necessity for the exchange of gases in the blood. Want of oxygen and over-accumulation of carbon-dioxide in the blood and the tissues generally stimulate the automatic nerve-centres of the heart to greater activity, and the number of contractions may thereby be enormously increased, until, in some cases, the heart-beats are three times their normal number.

Just as was the case with the lungs, abnormal rapidity of contractions on the part of the heart must sacrifice the thoroughness of its work. When the heart beats at the rate of 160 times per minute, the ventricles contract before they are half full with blood; the pulse, though rapid, is small and feeble, for the arteries are incompletely distended. The contractions of the heart itself are incomplete, being inadequate to the demands put upon it, and consequently we have as a result a momentary insufficiency of the heart, which, however, given a certain period of rest, returns

to the normal, providing the heart was originally sound and not altogether unprepared for an occasional demand upon the endurance of its muscular tissue for an extra amount of work.

A muscle, the functional activity of which, as in the case of the heart, is so intimately related to the action of all the other muscles of the body, also shares in the main the fate of the latter. It is exercised and strengthened the same as, if not more than, the other muscles by carefully systematized work, and becomes soft and degenerates through lack of exercise the same as they do. A certain amount of hypertrophy of the heart, as long as this is in proportion to the increased growth of the rest of the muscles, is not a disadvantage, but rather an expected and quite necessary gain. While no two hearts are exactly alike, the greatest possible difference is found between the heart of an athlete and that of an office clerk, yet both may be normal in their relations to the whole body. A strong heart is one of the essential conditions which determines beforehand the amount of work which a man is capable of performing. General weakness of the heart-muscle, distinct lesions or valvular troubles limit the amount of work a man is capable of doing from the beginning. The muscles of the heart must be trained through graded, systematic efforts just the same as other muscles, if a higher degree of working efficiency is expected. Since, however, the two cannot very well be trained separately, no special gymnastics for the heart are necessary, at least not under normal conditions, with which alone we are here concerned.

An untrained and unprepared cardiac muscle must surely give out on sudden demand being made on it for an unusual amount of work, and permanent injury is liable to be the result. Any muscle, in a state of fatigue, can easily be stretched beyond its normal resting limit and thereby loses much of its tone and elasticity.

It must, of course, be quite apparent that the muscles of the heart, when weakened by hunger, starvation or fever, must become prematurely fatigued, consequently this organ is much more liable to be over-distended in this condition when an unusually large quantity of blood is poured into its cavities, as is done during hard work. An over-distended heart will not admit of perfect closure of its valves, and to the inefficiency of the heart-muscle there is added the insufficiency of its valves. This sort

of inefficiency is, as a rule, very serious, and leaves permanent after effects which forever after disable a person from exerting his utmost powers without producing heart failure. Cases of rupture of the heart and of its valves have been observed everywhere, especially in connection with athletics. In a post-mortem which I had the opportunity of making on a young cadet aged 18 years, who was a very determined and enthusiastic high and broad jumper, a pole vaulter and hurdle jumper, the aortic valves were all gone, except a few narrow thickened shreds near the ring, where they were attached; the mitral valves also had nearly disappeared; this was the result of going into competition without previous training for the event.

Over-distension of the muscular walls of the heart with all its disastrous consequences may also be produced by heavy lifting. Heavy lifting results, as a rule, in over-distension of the right ventricle on account of the action of the lungs being suspended and their capillaries being compressed, thus preventing the flow of blood through them and thus from the right to the left side of the heart, consequently the right side must be distended with blood. The same condition exists during forced diving and for the same reasons.

There are certain conditions of the heart that would exclude its owner right from the start from any course of training whatsoever. If, for instance, it should be found that a slight amount of exercise would cause the heart to beat out of all proportion to such exercise, the chances are that, in spite of the appearances of perfect symmetry and health, there exists some malproportion as regards the size of the heart when compared to the blood-vessels to be supplied. At last there is the irritable heart, which reacts abnormally not only upon exercise, but also upon psychical emotions. All such cases are to be excluded from both the military and naval services.

Motor Nerves.—The seat of the will, in obedience to which all voluntary muscles may be caused to contract, is in the gray matter of the brain. From the cells composing this gray matter fibers originate and travel through the brain and spinal cord into peripheral nerve-cords, and finally terminate in muscular fiber. An act of the will, whatever that may be, means a certain amount of work done by these brain cells and, therefore, presupposes the loss of a corresponding amount of stored-up

energy in the brain; increased combustion and metamorphosis accompany brain work, just the same as they do muscular work. The nerve-fibers, simply conducting the various impulses from the brain to the muscles, seem to play a merely passive rôle in the process.

The strength of the ensuing muscular contraction is directly dependent upon the strength of the stimulus generated in brain-cells. It does but *seem* as if the muscle of its own accord produced the required strength for its contraction to overcome resistance. Sometimes we rather underestimate the amount of stimulus required for lifting a certain weight. The first contraction of the muscles is, then, not equal to the task and now a stronger stimulus is sent to the muscles and so on until the contraction produced is equal to the resistance to be overcome. An act of the will producing muscular contraction, in other words, a motor-impulse, is a product of work done by brain-cells and directly determines the strength of the muscular contraction that follows. The greater and the more intense the process of combustion going on in brain-cells is and the longer in duration, the stronger and longer also will be the muscular contractions that follow it. Both the energy stored up in muscle, as well as that stored up in brain-cells, is supplied from the blood; the blood also removes the products of wear and waste in rushing through these tissues. Inasmuch as it takes time to restore the lost nerve-energy, it is not difficult to imagine certain conditions and circumstances which would tend to completely exhaust it, and then muscular work would cease purely and simply on account of the absence of motor-impulses. Thus we see that fatigue of the brain and spinal cord may occur quite independently from fatigue of the muscles.

We know that during muscular contraction the blood-vessels in the muscle become dilated, and thus more blood flows through them than during a state of rest. The same increased circulation is met with in the brain during its activity. Energy is used up very rapidly and the waste-products are quickly removed. Like muscle, the brain cannot appropriate new materials from the blood to take the place of those that had been expended during a state of activity. Now, while a fatigued muscle will recover after a certain amount of *rest*, a fatigued brain needs *sleep* for its recovery. The increased blood-flow through the brain,

when in a state of intense activity, as well as through the muscle during its work, is chiefly intended to aid in the processes of combustion by furnishing the necessary oxygen and in removing the products of such combustion, but repair of brain energy can only take place during a state of rest, just the same as we have found to be the case with muscle energy. "During sleep we find the brain plentifully supplied with rich arterial blood; the better this supply the profounder also will be the sleep, and the more thorough, consequently, will be the repair of the lost energy." (L.) "Indeed, the drowsiness temporarily produced by over-indulgence in alcoholic liquors, finds its explanation in the arterial congestion of the brain which it produces." (L.) Overwork, forced marches, hard mountain-climbing produce the contrary conditions. The overworked muscles, with their dilated blood-vessels, require and hold within their meshes a greater quantity of blood than usual, and the likewise fatigued brain consequently cannot get its proper share, and for this reason sleep is either impossible or superficial or comes on later, that is, after the muscles have already returned to their normal condition and we wake up feeling perfectly rested so far as our muscles are concerned, but such sleep has not proved as refreshing as normal sleep usually does. In fact, the influence of a sleepless night upon our feelings is well within the experience of every one of us, and would go far in showing the great importance and necessity for a thorough and complete restoration of our lost energies and the direct dependence of their restoration on sound sleep.

If this condition recurs frequently, or if other conditions are combined to still more disturb and impair the normal process of nutrition of the brain substance, maximal muscular contractions and feats of endurance become absolutely impossible; forced marches are things of the past, and a condition, known as neurasthenia, the natural result. Neurasthenia, then, is the direct consequence of a disturbance of the proper balance to be maintained between supply of nutriment to the brain and demand of work done by its cells. The organ which produces the will has lost its very source of strength. The motor or voluntary impulses which are able to force into activity even fatigued muscles are themselves devoid of those substances upon the presence of which depend their auto-productive and creative energies. The condition known as endurance depends not so much on muscular

power as it does upon a strong will, and this again finds its *fons et origo* in a well-nourished brain. A lack of endurance also constitutes one of the cardinal symptoms of all neurasthenics. Among the more general causes which are productive of neurasthenia, besides actual hunger and a starvation diet, the principal ones are alcoholic and sexual excesses. These may be the causes that destroy the endurance needed just at the most decisive moment; through over-indulgence in such excesses, the benefits of a long process of careful training may be lost in a single night. If this happens among a number of soldiers just proceeding on an arduous campaign, these will be found unequal to their comrades, and the dangers of hot, forced marches will make as heavy inroads among them as they do among those entirely untrained and unprepared. It is not muscular strength that was lost in such a short time, but it is nervous energy or brain energy—the motor power has been destroyed and wasted. The muscles become prematurely exhausted, the heart muscles included, because that which gives them their endurance has been taken away. It is for this reason that athletes, while preparing for a decisive game or race, in both of which success depends upon every man's doing his duty to the very best of his ability, give their word of honor not to use either alcohol or tobacco nor indulge in sexual excesses during the period of training.

The training of a whole army corps is, however, not as easily protected against dangers such as these, and since a few may, nevertheless, endanger the success of a large body of troops, since the rapidity of their united advance is not that of the favored few, but that of the slowest among them, means to that end must be taken and attempts at corruption from that quarter guarded against with special vigilance.

As has already been mentioned, besides want of sleep, alcoholic and sexual excesses, hunger, of course, is the most direct cause of a want of nerve energy and endurance.

Any cause preventing the proper and timely supply of those substances in which our energies are stored up after they have been exhausted, must tend to make further work impossible without the very structure and vitality of the organs themselves becoming seriously attacked. At first this attack will be felt in those organs that are directly engaged in the work, but after-

wards the entire organism will be drawn upon and a general loss in weight will be the result.

To what extent and how profoundly hunger influences the activity of the brain may be seen in the expressions of impatience and irritability with regard to more or less all things shown by some people before meals, as compared to the more benevolent placidity which characterizes the same individuals after they have had their meals. This feature undoubtedly shows part of the animal nature of man. We know that every wild animal is particularly wild when attacked or in danger on an empty stomach, and it may be considered good and sound advice, if one man has an important favor to ask of another, that such request had better be made of him after meals than before, even under ordinary circumstances of life.

While this condition of temporary neurasthenia is quickly gotten over, continued starvation finally leads to real neurasthenia which is of longer duration. The will power is gone simply because the fuel has been used up. In this respect the human body may safely be compared to a machine that is insufficiently supplied with fuel, and, consequently, stops. Every well-informed husbandman knows from experience that the amount of work to be gotten out of his farm hands depends, among other things, largely on the quality and quantity of the food which they are supplied with, and every commander of troops should know and realize that the success of those troops, the endurance of long and fatiguing marches, the rapidity of his advance, will be in direct proportion to the quantity and quality of the rations that are supplied to his men.

Those of us who have had opportunities of watching men in training for either foot-ball or a boat-race know from experience that there comes a time when a few of their number begin to complain of lack of sleep at night, of drowsiness and general apathy during the day, and a general lack of endurance, both mental and physical. This is the condition known as "over-training" and the result of a disturbance of the normal balance between supply and demand. It may be that the normal limits of their capacity for training have been reached, if not surpassed, or the condition may also have been produced from lack of sleep, insufficient food, an intercurrent attack of indigestion, etc. In many cases it is due to neither of these causes, but rather

an indication that the maximum limit of the weight and strength capacity of the particular number of individuals concerned has been reached and their condition simply stands as the outward expression of this fact. Their nervous and muscular organizations refuse being developed to any higher degree of functional ability or efficiency. It is well known that there exists a natural limit in both directions for every individual, and every attempt to develop him beyond that limit leads and must lead to neurasthenia. This natural limit differs with every individual; it also differs at different periods of life for the same individual. As a general rule, it may be said that after middle life the normal period of repair of used-up energy begins to be lengthened or takes a longer time for its accomplishment, and, on the other hand, the energy itself, both muscular and nervous, is more quickly expended and used up than was the case during previous years, and consequently neurasthenia becomes more frequent in later life. The important bearing which these facts must have on training is self-evident. Consider for a moment the variegated composition of our army, navy and militia, as to the ages represented by the different men, not talking of the difference in their nationality. In the armies and navies of Europe we find that the age limit of the rank and file is limited to from 20-23 years, and forms a tolerably uniform factor in the problem. Much greater care and circumspection are necessary in the training of such a composite body of men as compose our military establishments than in Europe. Individualization is much more often called into requisition in the United States army than in the armies of Europe; a classification according to age previous to a course of training is almost as necessary as the required physical examination before enlistment.

It is a fact, admitted and accepted by the most experienced trainers, that a period of six weeks of training, provided such training has been graded and systematic, will result in developing the men to the utmost limits of their capacity. Every attempt to maintain this maximum condition of training for a longer period has invariably failed. Instead of obtaining a further increase in weight and endurance after the period of six weeks, the very contrary occurs, namely, loss of weight and especially loss of endurance, showing the nervous factor in the equation. In other words, after the period of six weeks we must expect the condi-

tion of overtraining to become general, if not a short period of rest follows the training.

Whenever the state of overtraining comes on prematurely in certain individuals, it may generally be known by the particular individuals not having gained the usual and customary amount of weight during the training period so far as it has advanced. It has been found in the beginning of training, generally during the first week, that a slight loss in weight occurs. This loss is followed, normally, by a steady and continued gain until the fourth week, from which time on the weight becomes steady and the maximum strength capacity of the individual is reached. Many a game of foot-ball, many a boat-race, has been lost owing to the fact that the team or crew was overtrained and *not* because their work was inferior; it is one of the most difficult tasks to convince an enthusiastic trainer that his men are in a condition of overtraining and need rest. Mere argument and advice will rarely suffice, and unless the medical officer has the necessary authority to enforce his suggestions, the resulting disaster becomes inevitable and may be foretold. Dr. Leitenstorfer speaks of having seen whole bataillons in this condition of overtraining. Those who show earlier symptoms of overtraining do not possess the capacity necessary for the event, whatever that may be, and should be promptly excluded if their health is to be respected and the success of the remainder to be assured. The usual and most common signs of neurasthenia are well known in the overtrained and are easily recognized: their character seems entirely changed, they have become extremely irritable and explosive in their expressions and demeanor; they are disheartened themselves because they realize their state of health, though unwilling to admit it; they have lost their former endurance and are quickly fatigued; continued training in such cases is not only useless, but generally results in permanent and serious injury.

Now in this condition of overtraining, the anatomical or histological integrity of brain and spinal cord is not necessarily impaired, the trouble being merely functional and temporary. The machine does not work properly on account of inadequate supply of fuel. Still, a still further abuse of these structures through continued and impossible demands on the muscles for work, may also finally lead to real structural changes and cause permanent disease of these organs. It sometimes happens that temporary

paralysis is caused by excessive work of certain groups of muscles, even during the period of training. A case of this kind occurred at the Naval Academy during training for foot-ball, in which one whole arm was paralyzed twice within five weeks. The arm was paralyzed for three days the first time it occurred, but the second time it occurred it remained in this state for two weeks. It is well known that the persistent and more or less systematic abuse of the muscles, especially by professional strong men and athletes, is bound to be followed by disease of the spinal cord. Besides the usual neurasthenic symptoms, the final outcome is the disease known as "progressive spinal muscular atrophy," which is followed by general marasmus and degeneration of the cord.

Leitenstorfer cites the case of a professional strong man who exhibited himself for some time and was able to swing a pair of dumb-bells weighing 120 pounds each, while his body was supported by his head and heels resting on the edges of two chairs. After a period of two years of such exhibitions, progressive spinal muscular atrophy declared itself.

Fatigue.—A study of the physiology of exercise shows clearly that muscular work is dependent on the simultaneous co-operation of at least four different organs or tissues, namely, nervous tissue, heart, lungs and muscle, and that muscular work must come to an end as soon as either one of these four factors gives out. Heart and lungs influence muscular work, of course, but indirectly; breathlessness and palpitation of the heart prove by no means that the working organs proper, muscle and brain, are exhausted or even fatigued, for these are able to continue their work just as soon as heart and lungs have recovered. Fatigue proper we call that condition of things in which muscle and nerve tissue cease to function normally. A very concise separation of muscular and nervous fatigue is not always easy, and often impossible. It is nevertheless interesting to know which of the two gives out the quickest in certain exercises, the muscle or the nerve, the will or the flesh, and the exhaustion of which of these two is the most essential.

It is a physiological fact that no electrical current, no matter how strong it may be, is able to produce so powerful a contraction of a muscle as is the motor impulse generated in the brain and conveyed to the muscle through the agency of its motor

nerve. It is, furthermore, well known that after these voluntary impulses for a muscle have ceased to prove effective, the same muscle may still be caused to give strong contractions by the application to it of electrical stimulation. It is clear, therefore, that the muscle was not exhausted, but was still in possession of a certain amount of energy available for producing work; the muscle would have continued to contract had the nervous impulse been strong enough to effect such contraction.

We see, then, that at least one of the causes of muscular fatigue seems to lie deeper and far beyond the mere muscular organ apparently concerned; its own strength is of no avail when the impulses it receives from the brain are not sufficiently strong to excite it to action. No doubt, muscle can be fatigued, but its fatigue occurs long after fatigue has become manifest in nerve tissue. It is the brain that limits muscular work, and fatigue finds its last cause in the exhaustion of those of the cells of the cortex from which motor impulses originate and are sent out. Some of us also may have witnessed the feats of strength that are done under the influence of an over-excited brain. The dementia and paralysis which follow certain maniacal excitements are examples which show the power and the sway which the brain holds over the muscles. A classification of the different forms of fatigue, although perhaps difficult in some cases, seems nevertheless desirable, and we therefore welcome the attempt made by Leitenstorfer, who makes five different groups of fatigue:

1. Muscle fatigue.
2. Lung fatigue.
3. Heart fatigue.
4. Nerve fatigue or true fatigue.
5. Neurasthenia, or the condition of overtraining, being a more or less abnormal condition and of some duration.

The term exhaustion, according to the same author, ought to apply only to the "highest degree of nerve fatigue affecting the central nervous system and involving the subsequent giving out of all the factors involved in the production of muscular work, including the heart's action." In a medical sense, and according to this definition of exhaustion, it would be "wrong to report a bataillon having arrived completely exhausted, say after storming a height and arriving on top covered with dust and

perspiration and somewhat out of breath"; nor would that term apply to a boat's crew after a long and fatiguing pull against wind and current when, in a very short time, both the battalion and the boat's crew, after some rest and without taking any nourishment, each in turn is able to continue on their respective duties. The condition in which the soldiers arrived was simply one of an acute temporary fatigue of heart and lung; the same is true of the boat's crew. In either, the muscular and nervous factors, though functioning badly, were by no means exhausted to such an extent as to require nourishment and sleep.

In further illustration of the above classification of fatigue, we will quote some of the examples given by Leitenstorfer in his work:

1. *Muscle fatigue.*—"This occurs in its purest form in heavy lifting, knee-bending, pulling up on the horizontal bar, whenever these are continued until the muscles engaged in the work give out entirely. Here the muscles are quickly used up, while pulse and respiration, though increased in number, would still support further muscular work. A short period of rest for the muscles involved removes this form of fatigue. In case such exercise is pushed to extremes, however, the muscles will swell up and become painful and then the sensations of fatigue in the muscles continue for days."

"During the tetanic contractions of muscles, or whenever certain groups of muscles are expected to keep rigid for some time, muscle fatigue comes on so much more rapidly for the reason that, in the contracted muscles, the circulation is for the time being almost entirely interrupted, the blood-vessels being contracted or compressed and carbon dioxide and the other products of wear and waste cannot be washed away nor fresh oxygen be carried to the muscles. This is also well shown in the act of holding a heavy weight out at arm's length and at right angles to the long axis of the body. In spite of the best efforts of the will, the weight held in the hand will sink until the arm is alongside of the body. Will power in this case was not exhausted, for a short period of rest of the arm muscles suffices to enable the same muscles to do the same work over again. The act, often repeated, would, however, finally involve the nerve centers in the brain and spinal cord which, after awhile, must share the fatigue in common with the muscular structures involved in the exercise."

2. *Heart fatigue.*—"Acute cardiac insufficiency puts a stop to muscular work in the case of a sprinter or a dancer, not because the particular group of muscles engaged in the work is exhausted, but because with a superficial pulse of 180-200 p. m., the heart contracting imperfectly and the blood-vessels being incompletely distended, the muscles do not receive a sufficient blood supply, and, consequently, of the necessary oxygen. A short period of rest will also suffice to remove this form of fatigue."

3. *Lung fatigue* "in its purest form is rare and can occur only in a person whose heart is in the best possible state of training, thus permitting the lung alone to put a stop to muscular work. As a more general thing we will find that heart and lung give out together, and this occurs when the trained soldier rapidly storms a height, over rising ground, fully equipped for war, during the hot season of the year. This form of fatigue also will be overcome by a short period of rest."

4. *Nerve fatigue or true fatigue.*—"This form of fatigue is not the result of short maximal muscular efforts, but rather of long continued average work or a large sum of often-repeated maximal muscular exertions, for instance, long marches, mountain-climbing, prolonged gymnastic exercises, heavy labor. The fatigue thus incurred cannot be removed simply by a short period of rest; rest under such circumstances must be supplemented by food and drink and sleep."

"Complete general exhaustion differs only in degree from this form of fatigue. A single day or night is often not sufficient for its removal, especially when sleep is not prompt in coming on and not profound while it lasts. Perhaps several days and nights are necessary to completely overcome the state of general exhaustion, but finally recovery will take place, providing the men were well trained and under otherwise normal conditions and the proper amount of nourishment and rest were secured."

5. *Overtraining*, or "the neurasthenia following fatigue from overwork. This condition is often the result of injudicious training. Inasmuch as it is neurasthenic in character, it belongs to the form known as true fatigue, depending, as it does, upon the exhaustion of certain nerve centers. In its relation to other forms of fatigue which it resembles in some respects, it is of longer duration, though not incurable. This form of fatigue is caused not by short maximal muscular efforts, nor by a large

number of average muscular exertions, nor by work of an exhaustive nature continued for days, but by work that is continued and constantly increased for weeks in succession far beyond the natural limit set by a given amount of nourishment and a given period of rest for recuperation."

6. *Over-exertion* "resembles more nearly an actual injury done to one or more of the organs engaged in doing or assisting in doing certain work. It may be produced by sudden maximal efforts as well as by continued efforts at work. Heavy lifting or forced diving, giving rise, as they do, to an undue overdistension of the cardiac walls, especially of the right side, may produce it at once. Into this category also belong the partial or total paralysis of certain nerves supplying definite groups of muscles. Pain in the joints and along tendons, caused by their swelling from continued marching, is also often due to over-exertion. Raw recruits often experience a painfulness in the joints, tendons, even bones of feet and legs, while in training. While the significance of such an occurrence is not very great, these accidents should be avoided for the reason that they are apt to cause an interruption in the training. Cramps are due to over-exertion of single muscles."

Practical Problems.—Having briefly summed up in the preceding pages the most important points with regard to the physiology of exercise, we are now prepared to approach the more practical problems involved in the training of the soldier.

We can scarcely make the simplest movement without calling into requisition the action of several muscles at the same time. Even in trying to exercise, for example, a single flexor muscle of one of the fingers, we must exercise at least its natural antagonist, the corresponding extensor muscle also. This double influence must be kept in mind, and is peculiar to every muscular exertion. Just as in tacking a ship and hauling on the yards, both braces are held taut, so also have we, in every muscular performance, two kinds of muscles coming into play, namely, those that do the actual work and those that would naturally antagonize their action. This sort of muscular action is well illustrated in all balancing exercises.

It is therefore difficult, if not impossible, to develop one single muscle by a certain exercise; on the contrary, the most insig-

nificant movement involves the concerted action of an entire group. It is also sheer nonsense to try and enumerate the names of all the muscles involved in a certain muscular act, for most every act of any account would require the enumeration of all the muscles of the skeleton, and a perfect rest of all the muscles can be found only in the " horizontal position of the body, with semi-flexed extremities, the body resting on a soft, elastic couch." We will now pass in review of the principal muscles engaged during the more natural movements required of the soldier and man-of-war's man.

1. *Position of attention.*—Standing in due military form is not a position of equilibrium of the bones of the skeleton. The position, on the contrary, is only maintained through the action of the extensor muscles of the back and those of the hip and knee-joints, together with their antagonistic flexors. The action of these muscles is required for the purpose of balancing the body in its upright position, and, consequently, they must perform a certain amount of work to maintain this position. It is of some importance to know that, in standing in this position the knees, though straight, are not necessarily to be pressed back *ad maximum.* In such a position as this the soldier is enabled, by practice, to assume an attitude at least approaching that of equilibrium from his hip joints up. Notwithstanding this, however, even under these circumstances the point of gravity falling somewhat in front of the line connecting the two hip joints, on account of the chest being pressed forward, work is done by the muscles of the back, of the buttocks and those of the back of the thighs and legs, the mere tonus of the muscles would not be sufficient in keeping the man from falling in a forward direction. Sideward motions are controlled by the tone of the muscles alone. In cases of sudden fainting fits, where men are utterly overcome by fatigue, during which all the skeletal muscles are as if suddenly paralyzed, consequently unable to act so as to maintain the skeleton in the upright posture, the body falls forward. This I have seen illustrated in men who underwent punishment and who were obliged to stand on the deck of a ship, keeping their hammocks on their shoulders during an entire watch of four hours; they would fall straight forward, like a rod, in an unconscious state.

In adjusting a fine chemical balance there comes a time when

both scales will be at rest and the tongue in the center and on top of the horizontal bar points straight upwards and is perfectly immovable, so that its tip would produce nothing more than a fine point on a piece of smoked paper held in suspension over it. Leitenstorfer, applying the method of Vierordt, studied the capacity for balancing on the part of a number of soldiers in different positions by suspending a piece of smoked paper over the points of their helmets. In this manner he produced a large number of cephalo-grams very interesting indeed, and showing that such a perfect balance as may be produced with a scale cannot be approached even by the best trained soldier. A study of these cephalo-grams would show above all that the excursions which the swaying of the body produces on the smoked paper are more extensive in the antero-posterior or sagittal directions than in a lateral one, these being in a proportion of 3 to 1; they show, next, that these excursions increase in extent from minute to minute or the longer a soldier is kept in a definite position, and, furthermore, that the excursions are smaller or least extensive in the best trained soldiers. The excursions are smallest in the sitting position, on account of the pendulum being so much shorter; they are larger in standing at "parade rest," still larger in the "position of attention," larger still in the same position with knees well pressed backward, smaller in the position assumed when shooting, on account of the basis of support being larger than in standing, and largest of all in the position of "knees bent," simply because in this position the basis of support is only two-thirds of what it is during standing.

Every soldier has learned from practice that a march of ten or twelve miles does not prove as fatiguing as will a parade of two hours' duration, and the privilege of stepping out after a long parade is welcomed as a great relief.

2. *Position of "parade rest"* or the "position hanchée" of the French, is also fatiguing, but less so on account of the work required of the muscles in maintaining the position than on account of the painful sensations of pressure exerted on hip, knee and ankle joints of the one side. In this position fatigue comes on sooner than in the position of attention, because in the latter the weight is evenly distributed between the two sides of the body, while in the former the weight of the entire body rests on one leg only.

3. *Walking.*—In walking the upper part of the body is slightly inclined forward, and consequently also the point of gravity. In order to prevent the body from falling one leg is swung forward. Since the hip joints stand slightly lower whenever the body is inclined forward, the leg while swinging to the front must be slightly shortened in order to pass over the ground without touching. In the meantime the rear leg is lengthened because the foot is lowered for the purpose of shoving the body forward, whereupon the rear leg is brought forward, swinging by the other like a pendulum and in a slightly flexed condition.

In Germany two kinds of military walking or marching are distinguished. The one implies a well measured, somewhat rigid step, the foot striking the ground sharply and flatly with the entire sole, body and head erect and kept well balanced; in the other the foot is not brought down on the ground with such force nor strikes it flatly. The first form of step is used on parade, and is therefore also sometimes called the "parade step."

The parade step, when practiced slowly and emphasizing, as it were, every detail necessary for its smooth and complete performance from beginning to end, has become one of the most valued means for the development of all the step-muscles, as well as the muscles that balance the spinal column and head.

The reason why this form of step is not used in ordinary distance-marching of a bataillon, but only as a parade step and as a means for developing the entire step-musculature, is because it is too fatiguing on account of all the muscles of the trunk and legs being in a state of rigid contraction during its performance. During long marches, therefore, and in order to spare the soldiers all unnecessary expenditure of energy, the easiest form of step, that which requires the least expenditure of energy for its performance without, however, allowing the body to become crooked, is allowed.

As regards the keeping of the chest well out and the body erect and slightly inclined forward, which is the rule both in the position of attention as well as in walking or marching and running, I was able to produce much better results by explaining to the men that this particular position was insisted upon not alone because it looks well, but for the more important reason that by maintaining this position all the internal organs, such as the heart and lungs, are in the most favorable position for the per-

formance of their respective functions; the lungs, by being free from the least compression, can expand more freely, and the heart, for the same reason, has the fullest play in all its movements, while the stomach and intestines are well supported by a moderately contracted abdominal wall, the contractions of which co-operating well with those of the diaphragm.

There are six groups of muscles that are more especially engaged in marching, and the proper and efficient development of which is of the greatest possible importance to the soldier: (1) The psoas and iliacus, which elevate the thigh; (2) the quadriceps extends the leg upon the thigh, throwing the foot forward, and when the foot is fixed upon the ground it raises the entire body weight by straightening the leg bent at the knee; (3) the various extensors of the foot and toes, situated on the front and outer side of the leg, elevating the foot and guiding it over the ground; (4) the very strong bundle of muscles about the seat which extend the thigh and pull it backward; (5) the muscles situated at the back part of the thigh which bend the leg upon the thigh and enable the foot to take hold of and grasp the ground; (6) the muscles of the calf which elevate the heel of the foot and advance the body forward.

Upon the proper and efficient development of the above six groups of muscles depends the success of the modern infantry soldier, and with him of the entire army. The Field Marshal of Saxony places the whole secret of modern warfare in the legs, and with good reasons, for by far the greatest and most important part of the work required of the soldier consists in marching.

In accordance with the importance of these muscles to the soldier, and in order that they be developed to the highest degree of efficiency, the most thorough and painstaking leg-gymnastic has been evolved and is practiced in the German army. This practice consists chiefly in slowly but thoroughly going through the different movements which together make up the parade step, and some of you may have seen German recruits going through the maneuver while passing some of their parade grounds. In order to realize the full value of this practice as a gymnastic exercise, I should advise you to practice it on yourselves, systematically emphasizing every and all the separate movements of the dismembered step.

Running.—This differs from walking, not only in the in-

creased rapidity and length of the steps taken, but in that the step is converted into a jump. While in walking one foot always touches the ground, in running there occurs a short period during which both feet are off the ground, as in jumping, and the body is thrust forward through the rapid forward extension of the rear leg.

The muscles which are engaged in running are the same as those that are engaged in walking or marching. During running the point of gravity is put much further forward than during walking, and hence the rapidity with which one foot is put in front of the other to keep the body from falling in that direction. Picture to yourselves a soldier loaded down with 50 pounds of equipment taking 170 steps in a minute, each step of the length of one meter, and you will realize in some measure the amount of work his leg muscles are required to perform.

The Germans also distinguish a so-called "jump step" in running. Just as the parade step or rigid step is derived from the ordinary walking step, is a "higher powered" step, just so is the jump step a higher grade of step used in running, of no practical value in itself but of *very great* value as a gymnastic exercise, and presupposing in the performer already a high degree of strength and elasticity. The jump step is in fact the parade step used in running. While in ordinary running the entire sole of the foot is put to the ground, when using the jump step only the two anterior thirds of the sole of the foot are used, both in supporting the weight of the advancing body as well as in thrusting the latter forward. This maneuver puts extraordinary requirements on the muscles thus engaged.

Jumping.—The same six groups of muscles enumerated above that are chiefly concerned in walking and running, are also the principal ones concerned in jumping. In the jump the discharge of the strength resident in these muscles takes place like a sudden explosion. The hip joint, knee joint and ankle joint being acutely flexed, and suddenly extended by the contraction of the extensor muscles, the body is hurled forward and upward. Before clearing the obstacle, the legs are again drawn up by the flexor muscles and held in this position until just before reaching the ground on the other side, when they are extended once more, in which condition they reach the ground, the weight of the body descending upon the lower extremities as if on a spring.

While then a successful *high-jump* depends upon the quick and powerful contraction of the extensor muscles of the lower extremities, it must not be forgotten that the equally sudden and powerful flexion of the thighs upon the abdomen, and the legs upon the thighs, their closest possible approach to the body until the knees almost touch the shoulder and the heels the buttocks, is an important element in its execution. A much higher obstacle is cleared with the same expenditure of force and elevation of body when the legs are well drawn up than when they are not, the difference ranging from ten to fifteen inches. In the standing broad-jump we do not get this advantage, and this is, therefore, a more accurate measure for the power with which the jumper can throw himself from the ground than is the high-jump. In the running high- and broad-jumps, proper co-ordination and an accurate eye as regards the point from which to jump off, to be acquired only by experience, are also quite essential.

Riding.—At first sight, riding on horseback would seem to imply but a very small amount of muscular work on the part of the rider. Indeed, it must be admitted, if there is any benefit derived through horseback riding, when considered as merely an amusement, the horse certainly deserves to get the lion's share of it, and gets it, too. While the horse is doing a more or less large amount of active muscular work according to its charge, its rider, on the other hand, is rather in a blissful state of *being* exercised, and in this way seems to derive by simple contact a certain amount of benefit from the more active exercise which the horse takes, in the same way that a parasitic animal derives the benefit from foods which his host must digest but without himself expending hardly any nerve force and very little muscular force.

It is, however, somewhat different when we come to study horseback riding as an accomplishment of the soldier. The more or less solid connection between rider and horse is formed by the seat of the former and the back or saddle of the latter. The connection may be likened to a ginglymoid joint, in which the thighs of the rider act the part of the lateral ligaments, allowing only a backward and forward movement. While, then, the seat and the inner surfaces of the thighs are closely attached to the body of the horse, the spinal column and legs must, in all the movements, be so balanced that they remain vertically to the point of gravity of the horse, unless other positions become necessary for

the purpose of either aiding or preventing certain movements of the horse. The muscles that are engaged in riding, therefore, are those that keep the head and body erect from the hips up, and this is done by the back and neck extensor muscles, and those that keep the inner surfaces of the thighs in close touch with the sides of the body of the horse, which is done by the adductors and the seat muscles. These muscles, when properly managed, form powerful aids in driving the horse forward. Inasmuch as even those of the muscles, by which the legs are kept in touch with the horse, are controlled by muscles having their origin in the hip or thigh, the musculature concerned in the act of horseback riding may briefly be said to be located in the seat and the thighs.

The soreness and stiffness experienced in the beginning of the exercise also is found to be confined to these regions and the back, especially the lumbar region. The amount of work done by the muscles of the legs is reduced to a minimum, because the movement of the feet in the stirrups is, comparatively speaking, slight, and consists only in an up-and-down motion requiring but little force. This may be seen in professional riders, in whom there exists a disproportionate development between thighs and legs, as may be ascertained by measurements. This disproportion also is soon developed in cavalry recruits.

A good horseman, in fact, depends not so much upon the amount of strength of his muscles as he does upon the development in his seat and thighs of a certain muscle sense or "horse sense," by means of which he feels the movements which his horse makes or is about to make, so as to enable him to give timely aid to his horse in favorable movements or prevent any that are not favorable to the accomplishment of his own purposes. Good horsemanship, indeed, consists in this very co-ordination, acquired either by experience or inheritance, this working together between horse and rider for a common purpose and to the desired end.

Horseback riding, even for the most accomplished rider, means the performance by the rider of a definite amount of muscular work, and must, consequently, in the end lead to a corresponding degree or form of fatigue. Aside from the consequences resulting from the active work of the muscles directly engaged in balancing, etc., those of the muscles and internal

organs that receive a merely passive form of exercise, a shaking up and jolting, will in time give rise to an increase in temperature and to an increase in the frequency of the heart's beats and the number of respirations. Still, riding alone does not lead up to even temporary heart and lung insufficiency, as is the case in running and other similar exercises. This only occurs sometimes on the turf during racing.

Swimming.—By virtue of our ability to retain a certain volume of air within our lungs, the specific gravity of our bodies is somewhat lighter than that of the water, so that we are enabled to float in it. In order to move about in the water or propel our bodies, certain muscular movements are necessary. In the forward movement the extensors of the legs are principally engaged, very much after the same manner as in the jump. The legs are drawn up close to the body, the thighs forcibly abducted, the legs extended and quickly brought together, feet describing a semicircle during the maneuver. The body slides forward owing to the pressure exerted by the inner surfaces of the legs upon the cone of water included between them. During this movement the arms must be extended in the forward direction, the fingers of both hands touch each other to facilitate the movement. Next follows the drawing up of the thighs close to the body by a contraction of the psoas and the iliacus, and this is counteracted by the simultaneous movement of the arms and hands backward and downward, effected by the muscles of the shoulder plate and the broad back muscle or lat. dorsi. The pectoral muscles attract the arms again toward the sides of the body, and the extensors of the arms throw the hands forward. In the meantime the back muscles keep the back hollow and the head well out of water. The respiratory muscles keep up a vigorous movement of the thorax, in which they are supported by the lateral movements of the arms.

The suddenly increased frequency in the number of respiratory movements made on the part of the lungs, which are needed to satisfy the suddenly increased want of oxygen in the blood, is proof of the large number of muscles that must be employed in the act of swimming. We have here, indeed, all the muscles of the trunk and extremities engaged simultaneously, and not only mere groups of them. And there is no difference either in the degree of their contraction between any of them nor in the

amount of work which they are doing; all the muscles are engaged in working to their best possible ability. It is this that makes swimming one of the best general exercises there is. Swimming, therefore, makes the greatest possible demands on the functions of heart and lungs, and presupposes that both are strong and sound; on the other hand, when carefully taught, swimming is one of the best gymnastic exercises for both of these organs.

Vigorous swimming, particularly against current and wind, is very apt to bring on pulmonary and cardiac insufficiency before the fatigue of the muscles engaged in the exercise is a complete one. This double insufficiency would occur still sooner were it not counteracted to a certain extent by the temperature of the water surrounding the body and which has a cooling effect. By filling our lungs well with air, we are able to float on the surface of the water and rest when fatigued.

Diving or swimming under water is one of the severest tests on the heart, especially its right or venous side, for besides the large amount of air already taken into the lungs immediately before diving, which distends it and compresses its capillaries at the same time, thus offering a great impediment to the circulation of the blood through the lung, we must, in addition, take into account the pressure upon the thorax which the column of water, resting above the body, exerts on the outer surface of the chest walls. Thus we find that diving, just as much as the lifting of heavy weights, is one of the few exercises which may easily cause over-distension of the heart muscle. Persons having had rheumatism or suffered from some infectious fever, or who have indulged excessively in the use of alcohol and tobacco, must take such exercise with caution.

While walking, running, jumping, dancing, riding and swimming form the natural and, at the same time, simple bodily movements, the remaining movements of the soldier, such as climbing, pole-vaulting, fencing, all apparatus work, calisthenics, bicycle riding, skating, etc., are the combined body movements in which upper and lower extremities are engaged more or less simultaneously, and form mutual support and aid to one another. In such combined movements we find, in the first place, that they engage a greater number of muscles at one time than is the case with the simple and more natural movements. Thus, in climb-

ing, we have the muscles of the shoulder girdle and of the arm strongly supported by the muscles of the inner side of the thighs and legs. In pole-vaulting, although most of the work being undoubtedly done by the arm muscles, those of the lower extremities come into play in jumping off the ground. In bilateral fencing we find pretty nearly all the muscles of the body and the extremities engaged, although in exclusively right-handed fencing it often occurs that we get a unilateral hypertrophy of the respective arm muscles, and, on rare occasions, also, curvature of the spine occurs.

Bicycling is more nearly a natural exercise in spite of its being performed on a machine. It is but a modified walking, and exercises more especially the step-musculature with this difference, that the muscles of the seat remain rather inactive as compared to the muscles of the thighs and those of the legs. For the development of the calf-muscles, bicycling and mountain-climbing are about equally good. Bicycling, it must be remembered, puts very heavy demands on heart and lungs on account of the tendency of some of the riders to get over the ground as fast as possible, as is done in scorching.

Wrestling, like swimming, engages all the muscles of the trunk and of the extremities, but while in swimming the resistance offered to muscular action and to be overcome is uniform, that which is required during wrestling is irregular and not always easy to foretell; it trains the eye to quickness in action. The same is true for bayonet exercise. There are, besides, a number of these combined movements as distinguished from the natural movements, many of which are done in the gymnasium. From a study, however, of the anatomy and physiology of the natural movements described in the foregoing pages, their intent and purpose may easily be inferred. The same is true of the few exercises that are comprised in what is known as the setting-up drill, and to which, as a general thing, much more importance is attached than it deserves.

The classification of these free movements, as well as those done on the different apparatuses in the gymnasium, must be left to the judgment of the instructor or trainer and the purposes he has in view in applying them to the individuals under his care and in his training. It should always be kept in mind that there must be a definite aim as regards every individual's development.

the exercises being merely a means to attain a certain well-conceived end.

THE PERSONNEL TO BE TRAINED.—All military training naturally divides itself (1) into the training of the individual soldier and (2) into that of a large body of men as a whole. The object of the former is to train the man, develop his individual physique, loosen his joints, strengthen his muscles, raise the standard of his health and endow him with endurance in walking, running, jumping, etc.; the object of the latter consists in the employment of such means as are best calculated to still further develop the qualities acquired in the former and assure their continuance and maintenance. The principal exercise employed to attain this end consists in marching, which shall be brought up gradually to approach the conditions that obtain in an actual campaign and resembling in all its details those of war.

It is of fundamental importance that the military trainer should, first of all, know the *personnel* which it is his duty to train, and for the purpose of obtaining that much desired knowledge, a thorough examination must precede the training itself. At Annapolis, the instructor of gymnastics, acting as recorder, had the advantage of being always present when these preliminary examinations were made, and consequently knew as well as the director himself what were the good as well as bad points about the physiques of the different individuals who were about to begin training.

The first impressions of a new class upon both the director and instructor, although they had already passed the Medical Board, were often not exactly encouraging, and if this was the case with cadets, how much more so must this be the case with recruits. The ideal of symmetrical physical perfection, which is gradually formed in the mind of an experienced trainer as the result of years of experience, is so rarely reached by even a single individual out of many that annually present themselves, that it appears to him more and more evident from year to year, and as his experience increases, that without individualizing, his task would be a hopeless one. For even among an apparently well-selected class of people, round shoulders, slight spinal curvatures from faulty positions during childhood, with unsymmetrical hips and shoulders, drooping heads and bow-legs, deficient develop-

ment of the back and arm muscles, may all have their representatives in even so small a number as one hundred. Fortunately, though, as long as heart and lungs are perfectly sound, these are, nevertheless, attended with results often quite remarkable in the hands of judicious and careful trainers who know the importance of individualization and have experienced the great advantages of the use of special exercises. Training, perhaps more than anything else, requires patience, for many of the most uncomplimentary, even intemperate, remarks made by onlookers often concern men of the greatest promise, and those who turn out in the end the very best subjects not only as regards endurance in drills but also on parade.

Almost the first criticism that will be made, not only by the public, but by officers as well, when watching a military drill or parade, is sure to be with regard to the symmetrical carriage of one or two persons in the ranks. It is no doubt a great desideratum that every officer and man in the ranks should learn to so control his anatomy as to form a homogeneous link in the chain of his bataillon; that he should be ever conscious of the fact that he is one of the wheels of this great, living machine, and that he alone would be all-sufficient to destroy the beautiful symmetry of a parade, or that upon him alone might depend the success or failure of an assault. Indeed, a knowledge of the importance of concerted action on the part of every man within the ranks is looked upon as one of the pedagogical results of any and all the drills in which many men are engaged at a time. A parade, however, should never be looked upon as the *end* in the education of the soldier, but only as one of the *means* to that end.

The chief qualifications that determine the military fitness of a man are height, weight, lung capacity, strength, chest circumference, and their mutual relations to one another. These, together with a pair of good lungs and a sound mind, are necessities. Whenever the material to choose from happens to be unusually large, other points of a less essential nature may be taken into account. But much greater care and attention of course must be exercised in the physical examination of cadets than is done in the examination of recruits, for obvious reasons.

With the view of establishing a series of more reliable and trustworthy standards, and giving greater definiteness, as it were, to the extent and amount of certain recognized normal and,

therefore, allowable deviations, an attempt was made a few years ago to work out the averages with their normal deviations in certain dimensions, such as height, weight, circumference of chest, etc., from a large number of measurements that had been recorded during a previous period of thirty years, and arrange these data according to age. The measurements from which these calculations were made having been originally taken from normal subjects, that is, cadets who had passed the Board of Medical Examiners, it ought naturally to follow that the deviations calculated from an average standard previously established for certain dimensions must also be within strictly normal limits. This, indeed, was found to be true, and the tables which were published in the report of the Surgeon General to the Secretary of the Navy for 1893 have since been in constant use at the Naval Academy as aids in the examination of cadets.

In a general way, however, it is perfectly true and in accordance with our own experience, when Leitenstorfer states that "in spite of such attempts having been made, the physical fitness of the soldier cannot be expressed by any mathematical formula." The eye, experienced in training as well as examining men, may often be relied on when numbers fail to do so. No amount of experience, on the other hand, will absolutely always insure against failure in regard to individual cases.

Military training in general.—The training of men for military purposes and achievements while differing in many ways from that employed for the various sports and athletic events, has also, on the other hand, many features in common with it. The aims and ends of all training must include a higher standard of health, greater endurance, more will power and an ultimate increase in weight. All these may be attained by means of well systematized muscular exercises.

By measuring a large number of professional foot-ball men, runners, oarsmen, infantrymen, cavalrymen and sailors and averaging their measurements in different dimensions, we would undoubtedly arrive at certain figures corresponding approximately to what might be called (but is not) a type for each of these classes of men. Yet these figures at best would only represent anatomical facts, and, as such, tell us nothing with regard to the physiological functions which each type represents. I can conceive of the possibility of the measurements of two or even

three out of the above number of types approaching each other so closely that, so far as measurements alone are concerned, they might all be placed into one and the same class or type. One group of measurements out of these three might represent a typical foot-ball player, the second an infantryman and the third an oarsman. These three are chosen as instances because they happen to present much the same development as regards the muscles of their backs and legs, consequently would be most likely to be placed into the same class from measurements alone and without taking into account their previous history. Yet it is not to be expected that the one could be substituted by either of the other two so far as his skill and his special accomplishments are concerned, and the training for which has given him his physique, without material detriment or danger to the success of the game, race or maneuver. This would show that we may arrive at the same ends, so far as muscular development alone is concerned, in many different ways and by more than one method of training; it also shows that a well-developed foot-ball player is not necessarily a good soldier, nor a thoroughly trained soldier a perfect oarsman, in spite of the muscular development of each being much the same. All three have been trained for different purposes and are consequently *physiologically*, if not anatomically, different.

We know, furthermore, that the period of training for any of the sports must never be extended over a time of six to eight weeks on the average if we wish to avoid the consequences of overtraining. The period of training a soldier is extended over a much longer space of time. The various branches peculiar to the calling of the soldier or man-of-war's man require as much training and leave as sure an imprint on their anatomy and physiology as do the most complicated muscular movements. An essential difference in the training of a soldier as compared to that of a man-of-war's man is, moreover, to be found in the period of life at which each begins to learn his calling. A sailor begins young, and before his period of normal growth and development is completed; while the soldier does not generally enlist before he is twenty, an age at which growth, in height at least, is nearly at an end. Both need, therefore, different treatment, not only as compared with each other, but also as compared with athletes generally. This fact, however, remains true for all, namely: The

highest degree of efficiency within the limits of a man's capacity having been reached, it cannot be long maintained, either with or without detriment to his health, and a period of comparative rest must follow, and is quite imperative after the period of training. Nor does the training of a soldier or sailor mean that he should constantly be kept at the highest point of physical endurance and efficiency. This sort of training is to be undertaken only periodically and, in Europe, generally precedes the great annual fall maneuvers.

While it is perfectly true, and must be admitted, that in adults, the period of training being over, the former condition of bodily physique returns in about the same period which was spent in training, it is equally true and quite significant that a certain permanent and lasting addition accrues to the organism as regards height, weight, lung capacity and muscular strength over and above the normal *in persons who had not reached the adult stage of their normal physiological development*, or about 21 years of age, when undergoing training.

And, even in adults, long after the condition of their highest physical efficiency and endurance has passed off and their former natural physique has returned, certain permanent gains can be noted which, according to Leitenstorfer, are as follows:

1. "An acquired freedom in the articulations."

2. "An increase in muscular development which, under the influence of a moderate amount of exercise, may be maintained for years."

3. "Increased co-ordination of muscles; a certain muscle-memory has been created, by means of which all the movements are quickly recalled, even after years. Ex., the mere sight of a musket will cause the veteran to go through all the movements which its contact with his hands seems to suggest."

4. "A larger lung capacity and a stronger heart with freer circulation."

5. "Moral strength from consciousness of power. In other words, the normal standard of his health and strength has been raised far above the former average, he lives on a higher plane and has acquired more tone throughout his entire organization, which is ready at any moment to be again trained, in a short time, to the highest possible degree of efficiency and endurance."

Individual Training.—For the best of reasons, Leitenstorfer insists that "it is not, and must not be, the object of individual training to at once fit the soldier for enduring long and exhaustive marches, such as he is expected to perform in the end and to endure without danger to his health or the condition of his training." In this respect the training of the soldier is different from that which is employed for the runner, foot-ball player or oarsman. These are trained for an event which is soon over, while the soldier must be carefully trained for a career which may last for years. To start with, the most careful and gradual development of the entire step-musculature is to be aimed at, and this object can be attained only by a precise analysis of the step itself and by emphasizing every movement necessary to complete it. The soldier must be taught to walk and step out vigorously, get over the ground at the rate of 80 centimeters per step, endure such walking for days and over great distances, his body being heavily laden, and arrive in the field still fresh enough to go into battle. There is no calling, no athletic sport, which puts such heavy requirements on the step-muscles as are demanded from the soldier taking to the field. In view of such demands and requirements, we must find it most logical that the step-musculature of the recruit should receive the greatest possible attention from the very beginning. There is but one disadvantage, and a serious one, in this method of exclusively training the step muscles without having due regard to the other parts of the body. Such training must result, and generally always does result, in the asymmetrical development of the body as a whole, and direct measurements have proved this to be the case. It is found that the muscles of the back and legs are developed at the expense of the muscles of the arms and upper parts of the body.

While, then, says Leitenstorfer, "the systematic exercise or practice of the different and distinct movements of the dismembered step has proved itself to be the most valuable gymnastics for the development of the step-musculature, it must be supplemented by exercises which tend to develop the arms and the upper part of the body, and should not be too rapid." The soldier needs good muscular development of his arms, his shoulders and his neck for the purpose of an erect, strong and enduring carriage for climbing fences and other obstacles as well as for shooting.

Those who have had experience in examining and measuring recruits will no doubt agree in that there exists a greater difference or discrepancy between the strength of the arms of different persons than between their legs. We have even found it one of the most difficult undertakings to develop the muscles of the arms of different individuals and the upper parts of their bodies, in order to correct faulty carriage, naturally resulting from such weakness. These muscles seem, at least, to respond less promptly to the influence of exercise than do those of the lower back and lower extremities.

The soldier who is supposed and expected to carry a heavy knapsack on his back, with leather straps over his shoulders, needs good muscular cushions to keep those things from pressing upon the chest-walls, thus impeding his respiration and chafing the bones, at the same time allow the free and unhampered movements of his arms.

All this proves the necessity and importance of attending to individual faults in recruits. A company of recruits may, not inaptly, be compared to a chain in which every link possesses a different degree of tensile strength. While it is impossible to so train and develop every recruit that each one shall be the exact equal of his fellow in both endurance and strength, as can approximately be done with the chain, this must, nevertheless, be our aim; for it has been said, and truly so, by experienced generals, that the rapidity of the advance of an army is not the rapidity of the swiftest, not even that of the average, but that of the slowest; just as the strength of the chain is not that of its strongest, but only that of its weakest links. It is of great importance to advance the whole army, every man being of consequence, especially so in modern warfare.

In the light of facts such as these, is must seem clearly absurd and contrary to the end in view, to train five or ten per cent of a bataillon to do athletic feats, while the remaining ones look on and applaud, and it should never be forgotten that the highest aim of individual training of soldiers is to produce as nearly as is in our power and as our means will allow that much desired homogeneity as regards endurance, in the ranks and out of them, which will enable the commander of troops to arrive in the field of battle with his entire army, and not leave the greater portion behind on the field, exhausted and broken down, thus inviting sure defeat.

I cannot do better for the purpose of showing the startling inequalities in many respects that exist among recruits of even the same age, than reproduce a table from Leitenstorfer. Measuring a bataillon of men, he found the following results, which are exhibited in the succeeding table:

Dimensions.	Limits.		Difference.	Measurements of Strongest.	Measurements of Weakest.	Average of Bataillon.
Height	177	157	20 cm.	173	165	162
Chest circumference	95–103	78–85	17 cm.	95–103	80–86	84–91
Weight	81	50.5	30.5 kg.	81	55	61.5
Upper arm	30	24	6 cm.	30	24	26.5
Thigh	53	45	8 cm.	53	46	49
Leg	38	31	7 cm.	38	31	34.5

If such discrepancies, as are exhibited in this table, are found among men of the same age, what are we to expect to find among recruits in whom even age is not only not a uniform factor, but the most variable of all factors, such as we find them in our army, navy and militia. In the face of such difficulties as these the task of the training officer seems indeed almost hopeless. We must also, in view of the fact that all recruits must sooner or later form a homogeneous whole, clearly see how useless it would be to train a few for the performance of feats of strength and neglect the rest. A high average working capacity of the bataillon must be the constant aim held in view, and to attain this end the weakest among the men are just the ones that require not only the greatest attention, but also the very best experience and judgment. All those, therefore, who are from absolute lack of natural endowments entirely unfitted to benefit from or endure the necessary training with its hardships must be early discovered and promptly excluded, lest they shall become a useless burden on the bataillon and dead ballast on its hands.

All these things require the experience and skill as well as personal devotion of the expert military trainer. A high average working capacity of the bataillon as an entirety, a high degree of uniformity in strength and endurance among the individual soldiers so as to approach almost the ideal condition of homogeneity, a perfect machine, equally strong in all its parts and without a single flaw; these are the objects of individual training.

Diet and Nutrition.—The human body consists, on the average, of 59 parts of water, 9 parts of albuminous substances,

6 parts of glue, 21 parts of fat, 5 parts of mineral matters and 1 part made up of extractive matter (creatin, creatinine) and carbohydrates (glycogen and sugar).

During the life of the organism the relative quantities undergo a constant change and readjustment in accordance with the requirements of its daily needs. No thought can be launched into the world, not a single finger can be raised, except through the agency of the fine fabric of brain and muscle substance. But accompanying the performance of both mental and muscular work there goes hand in hand a substantial loss of matter, which loss must be made good so that the disturbed balance may be restored. The craving, known as hunger, is but the outward expression of something needed inside, and the various forms of fatigue are nothing more nor less than so many different kinds of hunger located and felt in those tissues that need nourishment most, and consequently cry for it the loudest in the only way they can. It will be seen, therefore, that the relation which exists between any kind of training and nourishment is both intimate and important. Careful weighing has always resulted in showing that there occurs a loss in weight in the beginning of training for any of the athletic sports, but this initial loss is followed just as quickly and surely by a more steady and, finally, permanent gain. Thus the average gain in weight of twenty-five naval cadets in training for foot-ball within the period of two months amounted to 3.28 kilos. Out of this number, two showed no gain at all, one lost one kilo, the lowest gain was two kilos, the highest six kilos. According to Leitenstorfer, the increase in weight of recruits after three months of training was on the average 3.27 kilos, or almost exactly the same as was found in the cadets.

The initial loss and the subsequent gain in weight may always be observed during the training of recruits in which the diet is sufficient and can be controlled. The loss of weight is, very naturally, always greater in the well nourished and fat people, less great in the thin and poorly nourished ones. In order that the gain in weight shall be normal, attention must be paid to the quantity as well as quality of the food. Whenever recruits are undergoing hard training and perform an unusual amount of muscular work, their rations must be adapted to their needs, or a loss in weight, instead of a gain, is always sure to follow. It

has been repeatedly shown in Germany, whenever soldiers were maneuvering, the maneuvers approaching the conditions of war, on a peace ration, that they all lost weight, and consequently also the benefits of the training, which it, nevertheless, was the intention they should receive. Such loss has been known to reach an average of 2.78 kilos (L.).

We must agree with Leitenstorfer, who remarks, "Since the war ration for the army is, by regulation, a higher one than that allowed on a peace footing, it stands to reason that no one has any right to exact the unusual requirements of war maneuvers from soldiers who has not also, at the same time, the necessary authority to increase the soldier's rations." That the living organism in all its various functions *can be improved* by the judicious exercise of such functions under the strict observance of the laws of physiology, lies at the bottom of all training, mental as well as physical. But increased work demanded from either requires increased supply of fuel, if not the machine itself is to be worn out and ruined.

As a general rule, and for purposes of training, that diet is the ideal one which nourishes the body without burdening the stomach; in other words, a diet which supplies the necessary amount of albumen, fat and carbohydrates in the form which is most easily digested and assimilated. The growing muscles need albumen, and since during muscular work the fats and carbohydrates are being burned up, it becomes necessary in the first place to increase the amount of fat in the food. An increase in the amount of carbohydrates is not so necessary, because all the rations contain a superabundance of those foods that contain them. The most frequent errors and the most serious mistakes in the composition of rations occur with regard to the quantities of fat which is allowed, and which, in most of them, is much below what it ought to be.

The most valuable albuminous diet for growing muscle is fresh meat, especially fat beef. The vegetable foods that contain a large percentage amount of albumen, vegetable albumen, are not so easily digested; besides, they contain a large surplus of carbohydrates and are consequently too voluminous a diet for the purpose of supplying the soldier with albuminous food in this form. Fat beef, then, is the most valued albuminous food for men undergoing training.

During muscular work the muscle is not itself consumed as long as there is at hand a sufficient supply of fats and carbohydrates. An increased quantity of fat must be taken by those who are expected to do an increased and increasing amount of muscular work. Fat is the best fuel, and its presence protects the growing muscle from being itself consumed. Both fats and carbohydrates must, of course, be given in a mixed form. In case the meat happens to be too lean, the necessary fat must be added in the form of bacon or butter. No form of fat, however, is so easily digested, and consequently so little of a burden for the digestive organs, as is the fatty meat from our domestic animals.

It is evident, from what has been said, that an officer in command of a number of men is not doing his whole duty when he is satisfied to merely fill the stomachs of his men; he must also look after the quality of the food which they consume.

Another point of great importance is the quantity of water which is taken by men in training. Water must not only be pure and wholesome, but a certain quantity of it is absolutely necessary to a perfect diet. But the percentage composition of all foodstuffs shows that they all contain a not inconsiderable amount of water, and therefore it would not seem necessary that much water need be drank in addition to that which the food already contains. Indeed, it may be urged as one of the objections to the common ration of the soldier and man-of-war's man that it is too sloppy, too wet. Soups and similar slops, while no serious objections under ordinary conditions, during training are to be reduced on account of their occupying too long a time for their absorption, and thus form an unnecessary burden or ballast.

It has long been known that horses fed on moist grass, clover or oats, sweat on making the least exertion and have but little endurance. A large quantity of water taken with meals dilutes the food material as well as the gastric juice; digestion is much delayed and the absorption of the digested food is much retarded; the stomach is distended and unnecessarily burdened with ballast; the tissues themselves become too moist, if not altogether œdematous, and the combustion of fats and carbohydrates remains incomplete, while the deposition of adipose tissue is favored.

Besides the proper quantity and quality of a diet, we must have

a frequent and wholesome change. The most hungry stomach will refuse to be satisfied at times with the same food for all time. An exhausted soldier will often, even in a state of hunger, refuse the proffered food, preferring to go to sleep without taking the much needed nourishment and suffer the consequences, if there is an unwholesome sameness about the bill of fare.

The temptation of consuming too large a portion of the daily ration at one meal is also to be guarded against, and a more judicious division very desirable. As regards coffee for breakfast in the morning, it is undoubtedly a most desirable adjuvant. But it must be coffee, and not one of the numerous substitutes of coffee. Then, again, it must be remembered that coffee is only a nerve-stimulant and not a food. Coffee simply stimulates the motor nerves and cannot take the place of any other part of a perfect diet. In order to give the coffee or the tea the significance of a nourishing meal, we must add milk and sugar to it and eat bread and butter with it, with perhaps some bacon.

Alcohol.—We have seen in the foregoing when water is taken in too great quantity during training its use is anything but useful. It retards the effects of training and, in the fully trained, lessens muscular tension, overburdens the heart by increasing blood pressure, overtaxes the activities of the lungs, the sweat glands and the kidneys, consequently depresses the working capacities and the endurance of the men.

A still greater danger, however, arises from indulgence in alcoholic beverages. These affect the men in training, not only as water does, by unnecessarily increasing their ballast and retarding their digestion, but by a direct destructive action upon their energies and endurance. The question of the effects of alcohol and its derivatives on human organization has of late years been extensively studied in all parts of the civilized world, and is rapidly approaching the condition of final settlement among scientific physiologists. Physiologists are agreed that alcohol directly attacks the substance of the brain cells, and after a brief period of stimulating them to abnormal activity, finally paralyzes them completely. The prolonged influence of alcohol destroys these substances not only temporarily, but attacks their structure upon the integrity of which their continued activity depends. Experiments have established the further fact that alcohol is not a food, and cannot take the place of one. More-

over, the idea held formerly that its presence in the blood would retard the combustion of nitrogenous material, has also been entirely disproved, and it was found that instead of retarding it, it causes an increased combustion of these substances. Practical experiments made with alcohol on large bodies of men who had to endure long and fatiguing marches during the war of the rebellion have also conclusively shown that it is disadvantageous. We know of its disastrous effects in hot climates, and of the dangers of its use in the polar regions. Therefore, alcohol is not entitled to form any part of the rations of men in training, especially of soldiers.

Mental Training.—An experience of five years at the Naval Academy, where I was given charge of physical training, has taught me among other things the great value and influence which the mind exercises over muscular work. There is, in my opinion, no system of exercises, no code of law, physiological or municipal, no regulation or discipline, that does not need to possess elasticity sufficient for an occasional and timely relaxation, a special interpretation and application to suit the present and ever changing condition of men's minds, if otherwise we would depend on the best quality of their work. In superintending the exercises of the cadets and sometimes noticing how mechanically these were gone through with, and how far off their minds apparently were from the work, it was perfectly surprising to note the difference in the performance of the exercises that immediately followed a short rest, a few encouraging words, an earnest and well intended appeal to their manliness and an explanation as to the higher purposes, meaning and significance of the work in which they were engaged.

I am firmly convinced that the difference in the effects on the human organism to be obtained through muscular work from the different systems of gymnastics, is at least as much due to the personal influence of the individual instructor over the minds of his men, as it is due to the special inherent virtues of the particular system employed and as compared with another.

Different minds need also different treatment, and the experienced trainer, in order to obtain the same results in all cases, modifies his treatment to suit the natural requirements of the individual. The mental discrepancies which exist among a lot

of men are at least as great as the physical ones are, and since, as we have seen, muscular work is directly dependent on the condition of the mind, treatment of the latter should engage as much the attention of the trainer as does the development of the body.

There is, for example, the city boy, up to all sorts of pranks and always bent on mischief, trying to get everybody into trouble except himself; alongside of him we find the good natured but slow, if not stupid, country lad, still laboring under the depressing influence of the newness of his surroundings, and falling an easy prey to the pranks of the former. These must not any more be treated alike than they can be pressed into the same mould, at least not for the purpose of producing the best results of individual training. The sailor boy who, as a general rule, begins his training from four to six years earlier in life than the soldier, requires in this respect also much more careful training than does the soldier.

But over and above the merely temporary mood, the mere frame of his mind, stands the soldier's natural mental endowment, his intelligence and inherited mental capacity. This also must be trained and cultivated. Both soldier and sailor must be educated in order that they may become intelligent machines, and whenever a time should come when the necessary word of command is missing, that they shall go on working in the way they should without any command. The better the education, the better also will be the results of individual training. Moreover, while it must be freely admitted that in a military organization and for purposes of military discipline, it is absolutely necessary that a man should learn to subordinate his own *will* to that of his superior, his superior or trainer should remember that the man's *self respect* is not to be crushed out of him during his training, but must be carefully preserved and developed.

Thus it will be seen that the successful training of the individual soldier implies a certain amount of intelligent instruction, and forms in its entirety a most difficult and responsible sort of problem. *Caeteris paribus*, we may sum up by saying that the best soldier will be the one who has received the best mental training; and the best instructor the one who has the highest conception and the profoundest and broadest knowledge of his duty and his calling, coupled with the ability of communicating both to his men. The greatest and most successful commander

of troops will be he who has himself acquired the most thorough knowledge and appreciation of the principles involved in training his men, and is thereby enabled to constantly keep in the closest possible touch with the needs and requirements of the ever changing conditions of his troops during the great maneuvers of an actual campaign. A maneuver of so large a body of men as a commander is responsible for handling at these times, is an experiment in which every detail concerning the care of men must receive the greatest and promptest attention by the commander himself, in order that it shall be successful, because nothing can be done without his order, hence, also, his responsibility.

Training of the Troops.—The recruit having been gradually and systematically developed, understanding the use of arms, having, moreover, been thoroughly drilled in all the movements of the company, bataillon and the regiment; in other words, having received all the constitutional benefits and advantages to be derived from individual training, he is now ready and prepared to join larger bodies of troops. The training of the troop, as distinguished from individual training, consists, according to Leitenstorfer, "in the systematic and gradual increase in the efficiency for marching and in the maintenance of a high average ability and endurance."

Though we must accept it as a fact that the highest possible physical efficiency and endurance which a man is capable of reaching through individual training cannot be maintained for any desired length of time, either with or without danger to his health, it is nevertheless one of the outcomes of individual training that the soldier is kept in such a condition of physical perfection, so as to enable the commander to force his troops up to the point by a short period of training whenever the exigencies require this to be done. The recruit, moreover, cannot be considered ripe for troop training until he has successfully completed his individual training and passed through the various company, bataillon and regimental drills.

The period of troop training should never be extended over three weeks, since experience has shown that such efficiency and endurance, as is the aim of this training, cannot be maintained beyond this period without the troops passing into the condition of overtraining with its attendant dangers.

In the German and other European armies this begins in the fall of the year and ends with the great maneuvers, which, as we all know, approach in severity and in their demands upon the endurance of the soldiers the conditions of war as nearly as these can be anticipated and reproduced.

The greatest danger that threatens the maneuvering of large bodies of men of course is heat-stroke, but since the discussion of this would lead us too far, it is perhaps just as well to leave this subject for a future occasion.

Troop training must be regarded as the finishing touch upon a soldier's training, and a short period of rest, generally two weeks, should always follow.

Have we anything in this country that would approach such training? Is it desirable that we should? Are the requirements and conditions which we have to meet sufficiently different from those prevailing in other countries that we can afford to dispense with the complete and thoroughly efficient training of our soldiers and men-of-war's men and militiamen? Is there anything we could substitute for such training? These are some of the questions which we must ask ourselves, and I know of none in relation to the personnel of our military establishments that are of such *real* importance whenever the *efficiency* of the service is urged and made a prominent feature in the argument.

It is not for me to suggest reforms with regard to the technical training of our soldiers and men-of-war's men, and far be it from me to lose myself in vain and useless criticisms of existing conditions of things, but from a point of view of training and developing the physique and endurance of those whom we look upon as the bulwarks of our defense, much as yet may be learned from an examination into the methods employed by other nations.

DISCUSSION.

A PROPOSED UNIFORM COURSE OF INSTRUCTION FOR THE NAVAL MILITIA. (*Continued from page 228.*)

Lieut.-Commander ARTHUR B. DENNY, Massachusetts Naval Brigade.—Mr. Dohrman's paper is of great value to naval militiamen, since it emphasizes some of the hindrances to their development and points out a remedy.

The present uncertainty of the range of usefulness of the naval militia is a damper on the enthusiasm of both officers and men. While the part which the naval militia has to play in assisting the suppression of domestic order is pretty clearly defined, so that an officer can be moderately sure where it is best to direct his efforts in preparing for emergencies, it is not so clear what would be the function of any particular unit in case of war.

As Captain Taylor has said in a most admirable letter to the Navy Department, special duties must be assigned to each State organization, and "no general plan for all alike can be drawn up." The problem for each commanding officer is not only "for what would it be well that my command be prepared," but also "what is the most valuable part of the whole for which I shall begin to prepare in the limited time which can be given."

In solving this problem it is desirable that this preparatory work, whether it be much or little, be directed by a considerable professional oversight, so that those taking part in it would be assured that their efforts were being made where the results would best fit into a general scheme. Then, too, the proposed lecture staff would get an intimate knowledge of just how far and in what lines each organization could be depended on for service, and this knowledge could hardly fail to be of more value to the Navy Department than the rather indefinite information which it now necessarily has.

Mr. Dohrman's scheme for winter work errs, if at all, in being too broad. Such part of the men's leisure time as can be given to military work is pretty well taken up now with drill and unavoidable routine. Undoubtedly a certain amount of information could be and has been obtained, but the many plans and working drawings with recommendations for structural and other changes would require more men with both technical skill and a command of time than many organizations would be able to furnish.

I agree most thoroughly with the author's recommendation to have systematic and progressive instruction given by a lecture staff working on a large general plan modified to meet the case in hand, and I hope the idea will be carried out by the proper authorities.

Lieutenant JAMES OTIS PORTER, Massachusetts Naval Brigade.—That a uniform course of instruction for the naval militia is necessary all are

undoubtedly agreed, and the essayist suggests an excellent plan for such instruction.

His recommendation that a board be appointed to formulate a system, and that a bureau of instruction be created, should be carried out, but it must be remembered that most of the officers and men of the naval militia are in business and that their time is necessarily somewhat limited. Too much, therefore, should not be attempted.

The reconnaissance work, so admirably begun and carried out by the New York battalion, should be systematically taken up by all, and the work should be under the direction of the navigating officers of the several organizations.

A list of vessels for the auxiliary fleet should be made and data collected as to size, tonnage, speed, indicated horse-power. When such vessels are yachts, the places where they are laid up in the winter should be kept track of in order that they may be brought to their ports of fitting out as suggested by Captain H. C. Taylor; but to obtain the information and to make the drawings that the essayist recommends would, to my mind, be impracticable. So much time would be consumed in work of this kind that no opportunity would be had for the actual drill and instruction of the men.

I would sugest that instead of the creation of small traveling libraries, each State should buy all the books required and issue them to its naval militia.

Systematic instruction and guidance by the Navy Department is what the naval militia needs, but it must not attempt too much.

Commander J. W. MILLER, 1st Naval Battalion, N. Y.—The argument presented by Mr. Dohrman is so entirely in accord with the views of the New York naval militia, and with the work of its battalion during the past four years, that little room is left for criticism, and the discussion would be unnecessarily prolonged if I should give even a synopsis of the correspondence and articles written by the various officers of this State upon the lines laid down by the lecturer. I would, however, call the attention of those interested in the naval militia and its development as a coast defense, to the *Forum* of October, 1891, April, 1896, to reports to the Adjutant-General of New York, 1891 to 1897, to the Journal of the U. S. Artillery, Vol. IV, No. 3, and to the Proceedings of the Association of the Naval Militias of the United States, 1895 and 1896. The article in those Proceedings, entitled "Information and Boat Reconnaissance Work," by Lieut. Wm. H. Stayton, is especially worthy of notice.

If the lecturer has found a "vagueness and haziness" among members of organizations as to what their duties would be in time of war, the reason for such uncertainty lies not in the fact that the officers of the naval militia have not had a definite scheme, but that lack of facilities has prevented them from developing their ideas, and that, unfortunately, they have had to devote the first few years to overcoming local antagonism, as well as prejudice in certain quarters of the navy. The regular service, with its years of training, can scarcely understand the difficulties

which surround the development of a new force with a divided allegiance to state and government. The laudable enthusiasm of recruits desirous of gaining a sailor's experience had to be guided in order to turn them from the more congenial work at sea towards the immediate and important duty of coast protection. The natural desire of the citizen-sailor is for tours of duty on board the new men-of-war. This desire should not be altogether thwarted if the country wishes to enlarge the naval militia to a force proportionate to its true importance. It is also essential that the enlisted men should have a rudimentary knowledge of naval customs and exercises, which is only to be gained by an occasional cruise in a government vessel; but such cruisers must be secondary to the main object for which the naval militia is formed, that object being the defense of the coast line and the waters of the State. It cannot be too often reiterated that the distinct purpose of the organizations is to develop them both in discipline and numbers as a portion of the "second line of coast defense." As the marine policy of the country becomes more definite there will be added to this "second line of defense" a national reserve under the direct auspices of the General Government. The creation of such a naval reserve will naturally follow the development of the naval militia, and from the reserve the navy will be enabled to draw its war complement of officers and men. It is most reasonable to suppose that if we once created a naval militia of even a few hundred men in each State it would concentrate around it the seafaring interests of the various ports. The question, therefore, presents itself, how can the four thousand men now in the naval militia be instructed, not only to perform their legitimate duties, but to increase the small number to a force commensurate to the needs of the country? The fulfillment of this object is not at all difficult if the service will do its share. The responsibility as to whether the navy shall keep the militia closely under its fostering aid or permit it to drift away to the army is most weighty.

A special office should at once be created at Washington under the Assistant Secretary of the Navy, to be called that of the "Naval Reserve and Naval Militia"; it should have at its head an officer of high rank, and under his exclusive control a moderate-sized man-of-war; this vessel should make the rounds of the ports for the purpose of instruction and inspection. A large number of the new torpedo-boats should also be under the orders of this officer, one or two of them being stationed in each of the harbors where a properly organized naval militia exists. During nine months of the year these boats should be actively engaged in teaching individual militia crews the use of torpedoes and mines, the officers commanding them to work jointly and in harmony with the State forces. The man-of-war and torpedo-boats should be assembled during the summer months for different tours of duty with each of the battalions or with those in contiguous districts. A squadron of this nature, under the command of navy officers trained to the work of obtaining military information, will result in a similar and definite course of instruction, the details developing themselves quickly. Sufficient data have already been given by the lecturer, and notably by Captain Taylor in his letter

to the Assistant Secretary of the Navy dated December 12th, 1896. My experience goes to prove that the scope of work for proper coast defense is so great that the difficulty will be in concentrating it, and that the navy itself has much to learn concerning the interior waters of the country. There is no service which will help the education of the regular officers more than that gained by commanding torpedo-boats. In addition to this active fleet, the reserve fleet of the navy, instead of being laid up at one navy yard, should be distributed to each of the larger ports, provided the State authorities will give them wharf accommodations free of charge. It is difficult for the writer to understand why the Department should think seriously of placing all the reserve fleet at one yard, when, by distribution along the coast, the present naval militia could be at once increased from four thousand to at least treble that number. The argument for docking the ships in fresh water amounts to little compared to the instant development of a *personnel* for the navy. Our minds have run too much to *materiel*, and it is high time that patriotism, enthusiasm and local knowledge should be fostered and assisted in every locality from Maine to Texas and on the Pacific coast. With the reserve vessels laid up in different harbors, having on board a skeleton crew and commanded by younger officers thoroughly alive to the necessity of recruiting the naval militia, with the battalions drilling on board the ships during the winter months, we will shortly have a force which, in addition to its local information, has gained a fair knowledge of the intricacies of the modern man-of-war. These laid-up vessels will also be a focus around which a national naval reserve will be formed under conditions outlined by the writer on various occasions. The plan is perfectly feasible and only needs the co-operation of the regular service. The expense is trivial, the result will be immediate.

Replies to Criticisms of Essay on Torpedo-Boat Policy.

[See No. 81.]

Lieut. R. C. Smith, U. S. Navy.—I find I have not been sufficiently explicit on one or two points. The word policy has been used in the title in a perhaps limited sense to indicate building policy. This technical meaning seems to have passed current to a certain extent since the report of the so-called "Policy Board" on ship construction a number of years ago. With this understanding, it is apparent that torpdo-boat tactics could not have been discussed at any length in the space assigned, which proved no more than sufficient for the subject proper.

Another point in which I have been somewhat misunderstood is my advocacy of strengthening the bow for ramming. I did not intend to go as far as recommending ramming as a prime object. I do not believe that opportunities for ramming should be sought, but that if occasion arises, as in the sudden discovery of a vedette launch or torpedo-boat of not too large a size directly in the path, the option of ramming

may prove of great value. Of scarcely less value is the added security in case of accidental collision bows-on. Many accidents attest the great weakness of the boats in this regard. With the strengthening I advocate, and the straight knife bow, I am confident that a vedette launch could be cut in two without material injury to the rammer, and that the weak side of an ordinary torpedo-boat could be laid open with every possibility of escaping fatal injury on the part of the attacking boat; and in torpedo warfare these are greater odds than are usually demanded.

My estimate of 5 to 10 pounds for every ton of displacement is based on an interior 18-inch (in width) belt of wood and steel applied to the Cushing's bow on either side for 15 feet abaft the stem, the total weight of which was 600 pounds. The knife edge for 18 inches abaft the stem was poured in solid with resin. This weight corresponds with the lower estimate of 5 pounds. By using 10 pounds per ton and all steel instead of wood, the strength could be doubled or trebled. This is all the more possible now that the bow tube is abandoned in torpedo-boats.

This interior water-line belt was suggested as the result of an experience of the Cushing's in the upper Delaware river in December, 1895, when she came near being frozen in for the winter. Ice of two to three inches thickness had been broken up in a thaw and then caked solid to a maximum thickness of five or six inches in a sudden freeze. Without any protection and with steam that in clear water would have given 15 knots, she passed through 20 miles of this ice. The result was a few frames bent and one or two cracked, and the plates of one-eighth inch steel bent in between the frames. No rivets were started and no plate was punctured. There was no injury beyond the second bulkhead at 15 feet from the stem. The interior belting subsequently applied was located in wake of the maximum bending of the plates and frames and securely braced from side to side. The details were approved by the Bureau of Construction. I understand that during the past winter the Cushing encountered ice in large cakes of three inches thickness in Narragansett Bay and Providence river which she cut through with absolutely no injury to herself and with steam that would have given 16 knots in the open. Is not this a great thing for a light torpedo-boat to be able to do, and at the expense of the weight of less than one torpedo? I hope that our other boats may all eventually be equipped with the same or a similar contrivance.

In conversations on this subject I have frequently heard the argument that it would be better to employ a tug to go ahead, or to rig a temporary ice plow over the bow. In time of war both of these means would usually be out of the question. Even in peace times boats might be caught, as the Cushing was, with no tug or carpenters available and the ice rapidly getting thicker. Then in case of a collision, accidental or otherwise, there would obviously be no time for preparations. I think this matter of added strength in the bow is a little like the Texan's revolver; he did not want it often, but when he did he had quite a positive need for it.

I shall now take up a few of the criticisms individually.

Lieutenant Eberle (page 56) suggests lashing the target across an old sailing launch. Of course it was contemplated to use a boat for the target, as otherwise towing at speed would be an impossibility. This was in fact Captain Evans' original suggestion. Mr. Eberle's plan of requiring the torpedo-boat to discharge her torpedoes at the same time is a good one. With dummy heads, the ship herself could be the target.

With regard to his discussion of torpedoes in battle-ships (page 57), I doubt if they can be given up by any nation as long as the ships of other nations carry them. Of course the submerged positions are the safest in every way. Then it must not be lost sight of that the range, speed, accuracy and safety in handling of torpedoes are constantly improving, and that there is less reason now than ever for dispensing with them. If other nations could be brought to discard them it would be all the more reason for us to retain them. In a discussion of Lieutenant Niblack's prize essay of last year I gave my views on this point at some length.

The statement (page 58) that I believe vessels of the Yorktown class would make efficient scouts does not convey my meaning. Our Yorktowns are altogether too slow, but there are some foreign vessels of the class that make 23 knots.

I cannot agree with Assistant Naval Constructor Dashiell (page 63) that the 1-pounder is a suitable gun for the smaller type of boat. The principal use of the vedette launch is to give warning of the approach of torpedo-boats. She might by a lucky shot disable one of them. On the other hand, I believe that the torpedo-boat should not pay the least attention to her. Run over them if they get in the way, but do not answer their fire; it will only create more confusion. Even when the vedette launches open fire and discharge rockets it may be some time before the ship picks up the torpedo-boat. If the latter joins in the firing she only hastens her own discovery. Her best plan is to keep right on in silence as long as there is the shadow of a chance of reaching the main object, hauling off only when positively discovered at some distance outside of torpedo range.

The object of the gun armament in torpedo-boats is, to my mind, to afford a weapon for use against other boats. A boat, if unarmed, might be destroyed by her inferior in respect to torpedo armament. It is an object then to carry weapons that could be used effectively in circumstances similar to these. Automatic 3-pounders, as has been shown, can be carried on the weights allowed, and they have therefore been recommended.

As to the remarks about the destroyers (page 63), I believe that destroyers should be met by destroyers and not by gunboats and cruisers. All experience as far as peace manœuvres go has proved the latter course delusive. And I think we should have a type fit to send anywhere with the fleet, which of course points to the large boat.

Mr. Dashiell and Mr. Eberle are in accord as to the undesirability of installing torpedoes in large ships. It would certainly simplify matters to leave them out, but that is not a good argument. Nothing now is

simple. The side that has the intelligence to use the most destructive and most complicated weapons with the greatest skill will win.

I am in most hearty accord with Mr. Dashiell's remarks as to naming the boats (page 65). Foreign nations name powerful battle-ships after great admirals. It is belittling our great names to give them to torpedo-boats. The stock of young heroes will last for a long time. I myself am in favor of employing names of insects, fishes and animals. The only drawback is that the English have largely depleted the available supply.

Assistant Naval Constructor Gillmor's remarks (page 153) are rather difficult to reply to. He finds nothing to commend in the essay, but he does not make clear what types he would substitute for those he condemns. I gather by inference that he is an advocate of the Forban. If he is, I can understand that we are scarcely in accord. But as the Forban has been improved on and practically abandoned by her builder, notwithstanding the splendid performance of her machinery, it is not necessary to attach any great importance to Mr. Gillmor's advocacy.

The reply to the argument at the top of page 154 as to the 30-knot boat and the 26-knot boat is obviously that if the former is able through excellence of design of hull and machinery to command a greater proportional economical endurance, then by a reduction of machinery weights to the amount required for 26 knots the endurance will be still greater for the same coal; and by applying the saving in machinery weights to additional coal there will be yet another gain. From the very fact as stated by Mr. Gillmor that the economical speed varies so greatly in different boats it is obvious that there can be no comparison except at *full speed;* and I am of opinion, moreover, that this is just the comparison that is most needed.

His argument in the next paragraph does not hold for the reason that there is no object in building boats with a lower speed than 22½ knots. In fact I have shown that all the required features, such as armament, endurance, sea-worthiness and the rest, for the objects sought can be obtained in a 24-knot boat. Then what is to be gained by going lower? If all these features could be assured in a 30-knot boat, then so much the better; but it is something that has not yet been done. It is true as he says that flaming does not appear until the maximum power is approached; but of course the water disturbance depends only on the model and actual speed, and has nothing to do with the maximum horsepower it may have been decided to put in the boat.

It is to be noticed that in all of this he is opposing my argument for a moderate speed and is himself advocating a high speed, necessarily at the expense of other features. I shall refer to this again.

Next follows an argument as to speed in a sea-way (page 154), which, if it means anything, is to the effect that because under certain weather conditions a small boat may do as well as or better than a large one, it is the part of policy always to build small boats. Of course boats like ships have their periods, and they do not always strike them together; but everybody knows that generally speaking greater size means greater possible speed, endurance, comfort, sea-worthiness and carrying capacity;

and it is on account of the very different duties required, as shown in the essay, that it is thought desirable to make such a marked difference in the two types.

Bearing in mind Mr. Gillmor's criticism of my boat of moderate speed, attention is asked to this extract from his remarks (page 156):—"Expressed in a few words, the author's conclusion is that we should start in this mad race for torpedo-boat speed about where England now is and accept their latest type in one case, and in the other almost a duplicate of the last thing which the English newspapers chose [sic] to call a torpedo-boat." This is certainly quite opposed to my whole discussion of the speed question, and taken in connection with his previous criticism of my advocacy of moderate speed, puts me at a loss as to his meaning.

Lieutenant Niblack (page 157) does not think I have taken enough account of tactics as affecting the design of boats. Has he not possibly lost sight of the difference between torpedo-boats and ships? Ships must manœuvre together and fight in conformity with tactics, and hence tactics will exert a great influence on their type and homogeneity, both of battery and hull. Torpedo-boats may also cruise together and engage other boats in conformity with tactics; but when it comes to the supreme object of their existence, the attack of ships, tactics in the sense that Mr. Niblack apparently takes it, that is the art of manœuvring together, amounts to very little. The only tactics I have seen advocated with any show of reason is to separate and make a concerted attack from different quarters under cover of darkness or mist.

If the different features are determined for this purpose alone, the boats will be nearly enough alike to engage in the German close manœuvres at full speed, which are useful for training the eye and developing the nerve, but could not possibly be used in action. I believe at the manœuvres some years ago they had a division of torpedo-boats steaming along shore by day in close order at high speed and shelling a troop of cavalry on the beach. This was pretty, no doubt, and it required some sort of tactics to carry it out, but it had nothing to do with torpedoes.

I have tried to show in the essay that the scheme of division boats presents few desirable features from our standpoint. I may not be sufficiently acquainted with it. While Mr. Niblack is abroad he will have opportunities of looking into both these questions, and if there is really much of value in the German system and tactics I for one shall be glad to hear what he may have to say about them.

I am very much in favor of any exercises that will give officers skill and confidence in handling their boats, and I think any risks should be taken that do not involve the probable loss of the boat or lives of the crew. If these risks are not taken in time of peace, officers will not know how to take them in time of war. Consequently every opportunity should be utilized, such as navigating narrow waters without a pilot, going alongside of docks at speed in various weathers, making attacks under the search-light on dark nights, and manœuvring about a vessel under way.

PROFESSIONAL NOTES.

TO FIND THE GREAT CIRCLE COURSE BY INSPECTION.

By Lieutenant J. B. Blish, U. S. Navy.

If in the "astronomical triangle" PZM, for M, the celestial body, is substituted N, the place to which a vessel is bound, then the angle at Z, the "azimuth angle," becomes the "great circle course" from Z to N.

This angle can be taken by inspection from the "azimuth tables" by substituting (1) the difference of longitude for the "hour angle"; (2) the latitude of N for the "declination," when the "true bearing" will be the "great circle course" from Z towards N, measured from the elevated pole.

The azimuth tables issued by the Navy Department are computed for the sun only, and consequently their use for this purpose is limited to those cases where the place to which the vessel is bound is within the tropics.

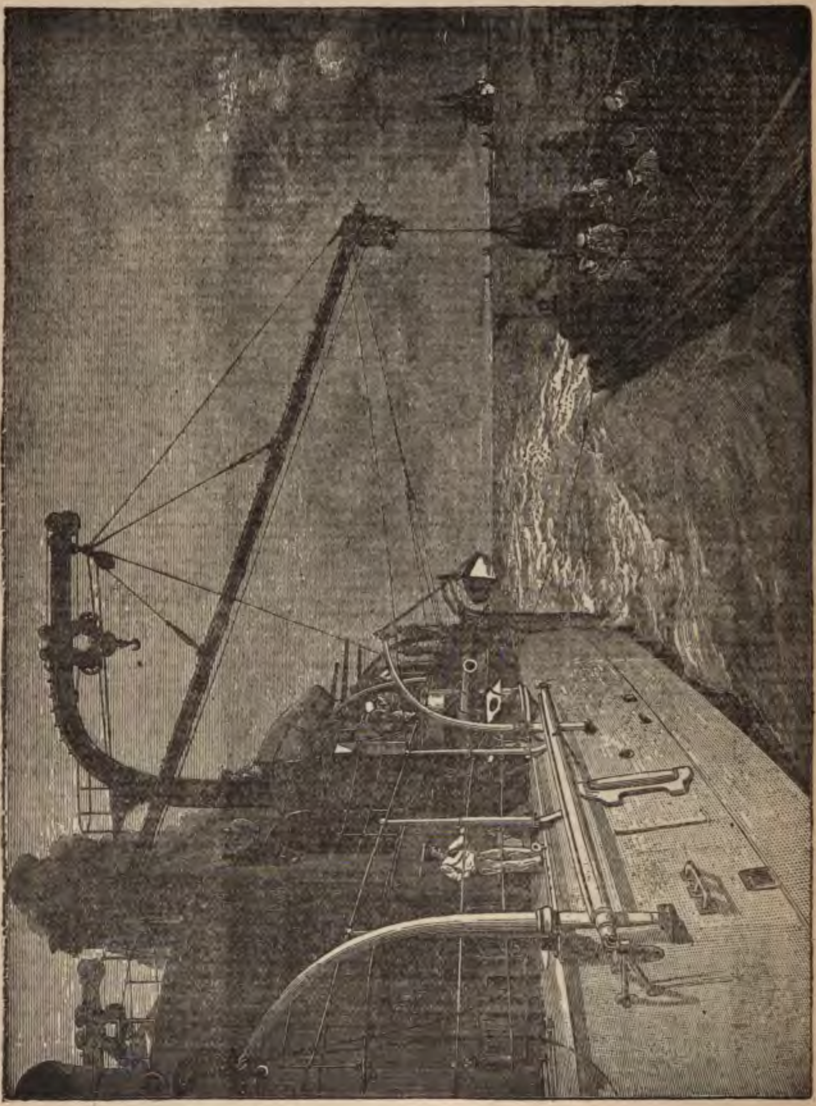
An extension of these tables to greater declinations would not only increase the number of stars available for azimuths, but by making this simple method available in all practical latitudes would tend to bring *great circle sailing* into common use.

COALING WAR-SHIPS AT SEA.

In dwelling upon the advantages conferred upon the war-ship by the introduction of steam, it must not be forgotten that the new power imposed one very serious burden which is making itself increasingly felt as the speed and size of modern ships continue to increase. For whereas the masts and sails of the frigate were good for a cruise of indefinite length, the boilers and engines of the modern cruiser or battle-ship are available for propulsion only so long as there is coal in the bunkers. The radius of action of the steam-driven ship is determined by her capacity for carrying fuel and her distance from an available coaling station.

There are perhaps no operations of a naval war in which this limitation of the steam battle-ship has caused greater inconvenience than in the work of blockading an enemy's port. In the days of the sailing frigate a ship could lie for months, if need be, in the blockading line, and the full strength of the fleet was maintained unbroken for months at a stretch; but in a modern blockade it would only be possible to count upon a certain percentage of the ships as available, the others being absent in turn, taking on coal at the nearest station. It has been estimated that during the blockade of Charleston in the Civil War fully one-quarter of the ships were absent at any given time for coaling purposes.

The same difficulty presented itself at the blockade of Charleston harbor during the recent naval manœuvres. Ships whose draft was not over 15 feet entered the harbor, where the water was quiet, and were coaled from



barges lying alongside in the usual way; but had the larger vessels, such as the Indiana, Maine, New York and Columbia, drawing from 20 to 26 feet, required recoaling, they would have been obliged to steam away

to Port Royal or Newport for the purpose. As it was, all of the vessels that took on coal were obliged to leave their position in the blockade, and its efficiency was impaired in proportion to the number of vessels absent at any one time.

With a view to overcoming the difficulty, the U. S. S. Massachusetts was recently fitted out at the New York navy yard with a coal transporter, which will enable her to take coal either when at anchorage off a blockaded port or when steaming at slow speed in moderately calm water.

—Carriage locked to the beam, the load being raised or lowered.

FIG. 2.—Load locked in the carriage which is free to travel along the beam in either direction.

The Temperly Transporter is the name by which this new form of hoisting and conveying device is known. The device consists of a traveler running on a suspended beam, which reaches out over the coal barge, towed abeam at a distance of 20 or 30 feet, and is carried from one of the boat cranes of the battle-ship. This beam, which is 60 feet in length, and weighs about 3000 pounds, is suspended from a strap, attached to the crane by four steel guys, and it is prevented from swinging fore and aft by means of other guys which lead inboard and are made fast to the

deck of the vessel. A novel form of self-locking carriage is employed, which travels upon the lower flanges of the beam, and is capable of traversing its entire length. The beam is pitched at an angle sufficient to cause the carriage to run out by gravity, and a single hoisting rope coiled about the barrel of the steam winch serves at once to operate the carriage and hoist the load. The rope after leaving the drum is led to a sheave which is secured at the point of suspension of the beam, from thence to a pulley at the higher end of the beam inboard, and from there it passes around a sheave in the carriage and terminates in a hook to which the bags of coal are attached.

In operation we will suppose that the carriage is at the lower end of the beam over the barge, where it is locked automatically to one of the stops on the under side of the beam, the locking gear of the carriage being then in the position shown in the first figure. After the hook is secured to the coal bag, the hoisting rope is drawn in by the winch, the load rises rapidly to the carriage, where a catch on the hoisting chain, striking a lever, automatically locks the load to the carriage and releases the car from the stop above-mentioned on the under side of the beam. This position is shown clearly in the second figure. The further inhauling of the hoisting rope causes the carriage to travel rapidly up the beam. The stops on the under side of the beam are spaced five feet apart, and the carriage is drawn up until it passes that one which is located over the point where it is desired that the bag shall be delivered. The winch is now stopped and reversed, and the carriage moves back until it is arrested by the engagement of the latch, which is shown at the top of the carriage with this particular stop. The dropping of the latch into the stop automatically releases the load from the carriage and it is forthwith lowered to the deck. The bag is then unhooked, an empty bag is put on in its place, and the operation is reversed, the empty bag being run down the full length of the beam and delivered to the barge. The whole operation is performed in less than a minute, and it requires no skill upon the part of the operator. The long reach of the beam permits coal to be taken from a vessel of any description, which may stand off from the battle-ship a distance of from twenty to twenty-five feet, and the operation may be carried out in any sea in which it would be safe for two boats to lie at anchor at that distance apart. As the transporter is supported entirely from the battle-ship, no part of it can be injured by the rolling from the two vessels.

It will be evident that the coaling ship may be towed at a moderate speed parallel with the war-ship, and that the operation may be carried out with equal success under such conditions. The French navy, which uses this system of coaling extensively, made a successful trial of coaling the Richelieu while she was steaming under the headway of six and a half knots an hour, and they were able on this occasion to transfer one hundred tons of coal in three hours.

After experiments extending over a period of two years, the British Admiralty has now decided generally to adopt the Temperly Transporter for use in battle-ships and first-class cruisers. It is probable that the apparatus would have been adopted before had it not been for its awkward length and the difficulty of stowing it clear of the working parts of the ship. The trials, however, have resulted in most favorable reports, and the commanding officers of the vessels in which the transporter has been tried are unanimously of opinion that the time and labor saved when

coaling ship far outweigh the inconvenience occasioned by stowing the gear away. Apart from this, it has been found that the transporter will enable a torpedo-boat or destroyer to fill up with coal from her parent ship when both vessels are steaming at a fair rate of speed, providing, of course, the sea is moderately calm. During a series of tests, forty tons of coal an hour were handled in bags by this device.

LIQUID FUEL.

[Paper by R. Wallis, read at a meeting of the N. E. Coast Institution of Engineers and Shipbuilders at South Shields on February 10, 1897.]

The writer's experience with this form of fuel has principally been petroleum residues on board of steamships, and the contents of this paper may, therefore, be taken as applying more particularly to its use in this direction.

The application of liquid fuel for the purpose of raising steam in boilers is now no longer in the experimental stage, a large number of boilers, both on board ship and ashore, being fired with this fuel, and there is no doubt that, as the numerous oil fields in the various parts of the world develop, its application will rapidly extend.

In addition to the oil wells of Southern Russia and Pennsylvania, oil has been found in varying quantities in most countries all over the globe. The late Mr. B. G. Nichol, in his paper on this subject before this Institution in 1886, mentions the countries in which petroleum had been discovered. Since that time several of these oil fields have been developed and are now producing petroleum in considerable quantities, especially those of Peru, Burmah, Sumatra, and Beluchistan.

The principal source of fuel oil is Russian petroleum residuum or "astatki"; this is the oil remaining in the distillery apparatus after the lighter naphthas and paraffines have been distilled over. Russian crude petroleum yields a very much smaller percentage of burning oils than American crude oil, as is shown in Table I, but fuel oil in Russia, where "astatki" is used for this purpose, is cheaper than in America, where crude oil is used.

The percentage of the various oils that, with the perfected process of distillation now used, could be obtained from Caucasian naphtha is as follows:

TABLE I.

		Density at 17 degs. Centigrade.	Percentage.
Light oils		0.725	3
Illuminating oil,	kerosene	0.822	30
	solar oil	0.863	14
Lubricating oils,	spindle oil	0.895	10
	machine oil	0.908	16
	cylinder oil	0.915	5
Oil fuel		0.93	17
Loss		....	5
			100

American oils contain a very much higher percentage of burning oils, about 80 or 90 per cent., instead of only about 50 per cent., as above.

The first steamer to use liquid fuel was the S. S. Constantine, on the Caspian Sea in 1870, and in America it was used on the steamer Thoroughfare in 1885. The first steamer to cross the Atlantic burning oil as fuel was the S. S. Baku Standard in January, 1894.

In addition to the petroleum oils, the following oils have also been used as fuels: shale oil, blast furnace oil, creosote, green, and other tar oils.

On the table are examples of Russian astatki, American crude petroleum, crude petroleum which has been exposed in a lake to the influence of the atmosphere for twelve months, creosote oil, heavy and light tar oils.

Comparing the value of coal and oil as fuel, it will be found to vary considerably according to the quality of the fuel and the circumstances under which each is burnt, oil doing from 1½ to 2½ times the work of an equal weight of coal; taking the average conditions, the results of extended experience with astatki and crude petroleum show that these oils will be found to do twice the work of coal.

TABLE II.

	Specific Gravity.	Chemical Composition.						Heating Power, British Thermal Units.	Theoretical Evaporation.		Evaporation in lbs. from and at 212° Fah. by experi-
		Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.		Lbs. from and at 212°.	Lbs. air required per lb. 23%.	
PETROLEUM.		%	%	%	%	%	%				
Pennsylvania heavy crude	.886	84.9	13.7	...	....	1.4	...	20.736	21.48	14.56	.....
Caucasian light crude....	.884	86.3	13.6	...	....	0.1	...	22.027	22.79	14.74	.....
Caucasian heavy crude...	.938	86.6	12.3	...	....	1.1	...	20.138	20.85	14.28	.....
Refuse	.928	87.1	11.7	...	....	1.2	...	19.832	20.53	14.12	16
Crude average, 15 samples	.870	84.7	13.1	...	....	2.2	...	20.233	20.94	14.29	.....
Refined average.........	.760	72.6	27.4	...	....	.....	...	27.531	28.5	17.93	.....
Scotch blast furnace oil..	.920	83.6	10.6	...	0.1	9.4	...	18.590	19.2	.....	.....
COAL.											
Welsh, 37 samples.......	1.315	83.8	4.8	1.0	1.4	4.1	4.9	14.470	14.98	.....	9.0
Newcastle, 18 samples ...	1.256	82.1	5.3	1.3	1.2	5.7	3.8	14.432	14.94	.....	8.0
Derbyshire and Yorkshire, 7 samples...........	1.292	79.7	4.9	1.4	1.0	10.3	2.6	13.582	14.06	.....	7.5
Lancashire, 28 samples ..	1.273	77.9	5.3	1.3	1.4	9.5	4.9	13.552	14.03	.....	7.9
Scotch, 8 samples........	1.260	78.5	5.6	1.0	1.1	9.7	4.0	13.804	14.29	.....	7.7
Average British, 98 samples	1.279	80.4	5.2	1.2	1.25	7.87	4.0	13.968	14.46	11.34	8.1

Table II shows the analysis of various oils and coals, together with their calculated calorific and evaporative values. This shows a value for oil of only 1½ times that of coal, and therefore some cause other than that of comparative heat value must be looked for to account for the result of a value of two to one in favor of oil fuel which is found in practice. This difference may be accounted for to a great extent by the following causes:

1. The combustion of the liquid fuel is complete, whereas that of coal is not; consequently in the former case there is no lost heat in smoke or soot.

2. There are no ashes or clinkers, and consequently no fires to clean, with accompanying loss of heat and drop in the steam pressure; the steam pressure and revolutions of the engines being maintained at one point throughout the voyage.

3. The boiler tubes are always free from soot and clean, and therefore always in the best condition for transmitting the heat from gases passing through them to the water of the boiler.

4. The temperature of the escaping gases may be considerably lower than is required to create the necessary draft for coal firing. With coal, the air has to be drawn through the bars and the fire in the furnaces; by natural draft this requires a temperature of the escaping gases about 600 degrees to 700 degrees Fahr. But in the case of liquid fuel there are no bars or thick fire for the air to force its way through, and the required amount of air can be drawn through the furnaces by a much lower uptake temperature, about 400 degrees to 450 degrees Fahr. being in most cases sufficient.

5. The admission of air to the furnaces being under complete control, and the fuel being burnt in fine particles in close contact with the oxygen of the air, only a very small excess of air above that actually necessary for the complete combustion of the fuel is required. With coal, in order to ensure as complete combustion as possible, a very much larger excess of air is required.

In addition to its higher calorific value, liquel fuel has many other advantages, especially on board ship.

Stowage.—A ton of coal will occupy about 45 cubic feet of bunker space, and a ton of oil will require about 40 to 45 cubic feet. Assuming that both coal and oil will require the same bunker space per ton, then since one ton of oil fuel is equal to two tons of coal, the bunker space necessary to steam the same distance at the same speed is only one-half. In addition to this, there is no lost space caused by the projection of frames, stringers or beams. Also portions of the ship which, if used as coal bunkers, would be inaccessible, can be utilized for the stowage of oil.

Trimming.—This is altogether dispensed with, the oil being run or pumped into the fuel tanks through a deck connection, and beyond the opening and closing of the distributing valves, no other attention or labor is necessary for the shipment of the fuel; this makes a considerable reduction in the labor, cost, and time occupied. When at sea the oil either gravitates to the furnaces, if the tanks are above them, or is pumped up if below, and no trimmers are required.

Stoking.—The sprayers require very little attention after they are once adjusted, and one man can attend to a large number of furnaces; and there being no ashes or dirt to remove, the stokehold staff can be reduced to a single man for each watch in any ordinary vessel, or in a small vessel the sprayers can be attended to by the engineer on watch in the engine-room, as is done in many of the vessels on the Caspian Sea.

There are also no firing tools to repair or fire bars and floor plates to renew, and the absence of smoke and dust enables the ship to be kept cleaner.

Regarding the various methods which have been adopted for the burning of liquid fuel, these may be divided into three systems: 1, Furnaces into which the oil is run or dropped and burnt without gasifying or spraying; 2, furnaces in which the oil is first wholly or partially gasified; 3, furnaces into which the oil is sprayed.

1. This is the oldest form of burning oil, and is illustrated by the following examples:

The step or cup form of furnace, and is the latest form of a very old method of burning oil.

The pan furnace of Biddle, used in North America in 1862.

Richardson furnace, patented in 1864. The bottom of this furnace is covered with ordinary slacked lime, which is kept saturated with the oil to be burned.

Audouin furnace, first tried in 1865, consists of a large number of small tubes from which the oil is constantly dripping, and is carried into the furnace and burnt by the draft through the openings in the front.

The furnaces of St. Claire-Deville, 1868; Wagenknecht, 1870; Kamenske, 1869; MacKine, 1865; Verstract, 1868, and Paterson, 1878, are all similar to one or the other of the above furnaces. The defect of all these is that the air is not brought in close contact with the burning fuel, with the result of imperfect combustion, accompanied by dense black smoke.

2. Shaw and Linton's gas furnace, patented in America in 1862.

Dorsett and Blythe gas furnace, tried in England in 1868 on board the steamer Retriever. It may be observed that the disadvantage of all gas furnaces is that when using heavy residual oils the tarry deposits rapidly stop up the passages and pipes.

3. The furnaces into which the fuel is sprayed can be divided into three distinct classes:

a. Flat slit sprayers.

b. Sprayers in which a jet of steam or air meets a jet of oil at an angle.

c. Circular sprayers.

Several attempts have been made to spray the oil by other means than that of the steam jet in order to overcome the difficulty of making up the fresh water drawn from the boilers in the form of steam.

Air under pressure, especially if heated, has been found to give good results, but the flame is shorter, giving a more intense heat for a short distance than the flame from a steam sprayer. More air than steam is required for the spraying of the oil, and the air jets are more noisy than the steam. The danger of an explosion of oil gas in the furnace and combustion chamber when lighting up, especially if the furnace has been stopped for a short time only, is very much greater with air than with steam sprayers.

Comparing the economy of air and steam sprayers (notwithstanding the drawback of having to make up the water lost in steam used by the sprayers), the steam sprayers appear to be the most economical, and are certainly the type mostly in use. The arrangement of the whole of the steam sprayer installation is exceedingly simple and not liable to derangement or breakdown, whereas the compressed air system is complicated and the risk of breakdown increased by the addition of the air compressor.

The essential requirements in a sprayer are: 1, The oil and steam openings must be so arranged that the oil can be sprayed in the finest particles possible; 2, the steam consumption of the burner must be as low as possible; 3, the sprayer must be constructed in such a manner that it can be easily and quickly taken apart for cleaning and quickly replaced; 4, the noise should be reduced to a minimum.

During the writer's experience and tests with a large number of sprayers, he has found that the "Rusden-Eeles" sprayer conforms more

nearly to these requirements than any other. The spray is very fine; in fact, with astatki the flame can be regulated so as to have the appearance and character of a gas flame. The steam consumption is low, and the construction allows it to be quickly and easily cleaned.

In the later sprayers the blow-through cock is omitted, it being found easier and more effective to take the tube out and clean it than to blow the oil space through with the steam.

In arranging an installation, the principal points are: 1, The superheating of the steam; 2, ample area in the fuel pipes, especially if heavy oil is used, and in the case of very heavy oils they may be required to be heated; 3, the supply tank should be placed in such a position as to ensure a constant and steady supply to the burner.

Brickwork in the furnaces should be arranged in a manner as to ensure the complete combustion of the fuel in the furnace and to prevent the too rapid cooling of the furnace after the flame is extinguished.

In some cases, where the boiler is placed in confined space or there is not height enough to obtain a steady pressure on the burners from the supply tank, the oil may be pumped direct to the burners if a controlling valve is connected to the steam pipe of the pump. This valve will regulate the speed of the pump automatically and maintain a constant pressure in the oil supply pipes, no matter how many sprayers may be in use.

In relighting a furnace which has been extinguished for a short time lies the greatest danger of explosion of oil gas and the accompanying back flash from the furnace doors. Any small leakage or drip of oil finding its way into the heated furnace gasifies and forms an explosive mixture with the air, and if the lighting-up torch is introduced into a furnace under these conditions an explosion is sure to take place, and the person introducing the torch is very possibly burnt. Before lighting a furnace it should be well blown through with steam and care taken to see that the steam jet is open first and the torch placed in the furnace before the oil valve is opened, in order that the spray may ignite as soon as it enters the furnace. If these precautions are taken there is not the slightest danger of explosion, even if fuel with low flash-point is used.

The result obtained by several experimenters, that the average evaporation of liquid fuel is twice that of coal, has been confirmed by a long series of experiments conducted by the writer under the instruction of the Wallsend Slipway and Engineering Company, Limited, with various sprayers.

The boiler, which is of the ordinary marine type, evaporated with coal fuel from 7 to 8 lbs. of water from and at 212 degrees Fah. for each pound of coal burnt, the uptake temperature being about 450 degrees Fahr. with Russian astatki. The evaporation was from 13 to 16 lbs. from and at 212 degrees Fahr. per pound of oil. The following are the average data from some experimens with a Rusden and Eeles sprayer, and a heat account from the same data:

Kind of liquid fuel, Russian astatki:

Specific gravity 0.9
Chemical analysis (approximate) .... 87 per cent.
Carbon .... 12 "
Oxygen .... 1 "
Temperature of stokehold .... 60° Fahr.
Temperature of escaping gases ....450° "
Weight of steam required to spray 1 lb. of oil......0.3 lb.

Assuming that the air contained 23 per cent. of oxygen, and that the excess of air over that required for complete combustion passing into the furnace was 20 per cent., which would be about correct, for the slightest reduction of air caused smoke to issue from the chimney:

	Heat Units.		Equivalent Evaporation from and at 212° Fah.
Total heat from combustion of 1 lb. oil :			
Carbon, .87 x 14,500............ =	12,615		
Hydrogen, .12 x 62,032............ =	7,444		
		20,059	20.7
Heat cost in waste gases at 450° Fah. :			
Carbonic acid gas......... 3.19 lbs.	269		
Nitrogen..................10.72 "	909		
Water vapor from combustion.................. 1.08 "	1,452		
Water vapor from sprayer.. .30 "	29		
Surplus air, 20 per cent.... 2.78 "	257		
		2,916	3.0
		17,143	17.7
Heat lost in radiant heat, etc...........		1,687	1.7
Heat absorbed by water in boiler........		15,456	16

In addition to the firing of boilers, liquid fuel has been used for various other purposes. Mr. Urquhart, in his paper before the Institution of Mechanical Engineers, shows how he has successfully applied it to scrap welding furnaces.—*The Steamship, April, 1897.*

THE DUM-DUM BULLET.

Surgeon-Captain G. S. Mansfield, Medical Staff, has drawn up an instructive report on the experiments with the special Dum-Dum bullet carried out before the commander-in-chief in India, at Meerut, in December. These experiments, which were intended to demonstrate the amount of "set-up" and "stopping power" in the bullet, were made, says the *Times of India*, on the carcases of freshly-killed sheep tied up in various positions, some with the fleece on and others with the outer skin removed. Except in one instance, the range was 200 yards, and the sheep were fired at broadside on, diagonally, and facing the shooter, in the last-named position the long axis of the body being exactly in line with the line of fire. The most remarkable result of the experiments was the large size of the "wound of exit." One bullet fired at an unskinned sheep broadside on passed between two ribs, making an entrance wound no larger than a big pea, but after shattering one of the spinal vertebræ, it smashed two ribs and produced an exit wound as large as a crown-piece. Another bullet fired under similar circumstances entered the abdomen behind the last rib, making a wound of entrance as large as a three-penny bit. On its exit a hole was torn in the opposite wall of the abdomen the size of a large orange. Yet another bullet fired at the same sheep pierced the lower jaw at its angle, making a hole in the skin no bigger than a pea, but on examination it was found that the bone was completely shattered. The report gives details of several other shots. One in particular may be noted, that in which the bullet, passing through the thigh, struck the pelvic bone, which apparently offered such resistance

that an exit wound 2½ inches in diameter was the result. Surgeon-Captain Mansfield mentions as particularly important, the case of a bullet which entered through the front of the shoulder-joint by a very small opening, and, passing through the joint, completely disorganized it. The articular ends of the two bones were smashed into over a dozen pieces and there was great loss of substance. This wound may fitly be compared to a shot through a man's wrist or knee, and under similar conditions the bullet would be certain to immediately disable him, excision of the joint, or more possibly amputation of the limb, being the only remedy available. It does not require an expert's knowledge, says our contemporary, to perceive that such wounds, if inflicted on a human being, must necessarily put an effectual "stop" to his advance, even if they do not always prove fatal. The efficacy of the Dum-Dum bullet is specially vindicated by the character of the wounds which only affected the soft parts. From these wounds Surgeon-Captain Mansfield infers that a bullet penetrating the muscular tissue only, such as that of the human thigh, will "set up" sufficiently to cause a severe wound, quite enough to effectually stop the progress of the man or the horse struck. It has been noted that all the shots except one were fired at a range of 200 yards. The exception was that of a shot fired at 50 yards from the animal. It struck the sheep's abdomen, soft parts alone being injured; yet though the wound of entrance was small, the bullet on emerging tore a hole the size of an orange. This shot exemplifies beyond all reasonable doubt the superiority of the new bullet over the old one. Bullets manufactured by the new method do not produce clean-cut wounds at close range, as was the case with the old bullets, but are now shown to possess an exceptional "stopping power."—*United Service Gazette, May 8, 1897.*

TESTS OF ARMOR AND SHELL.

[United States.]

Built-up Armor.

Washington, D. C., May 11, 1897.—The Navy Department has made an interesting test to determine the efficiency of two thin armor plates superimposed on each other in close contact, as against the resisting power of a single plate of their combined thickness, the result demonstrating to the satisfaction of the Department that the single thick plate is a considerably more effective barrier against armor-piercing shells with service charges than the thin plates. The experiment was made for the purpose of determining whether in case the emergency should arise it would be practicable to provide certain armor for the three new battleships by having thin plates made to be used in lieu of the thick plates, which cannot be produced within the limit of cost, $300 per ton, fixed by Congress in the Navy Appropriation bill. The thin plates, it was decided, could be manufactured by any one of a considerable number of steel makers and could be produced in large quantities at short notice at $300 per ton, or less.

The tests were made at the Indian Head Proving Grounds of two nickel steel, reforged, face-hardened plates, superimposed one on the other. The gun used was a 10-inch breech-loading rifle, No. 26, on a station hydraulic mount. The charge was 237 pounds of C. G. 2 powder. The

striking velocity, measured by the chronograph, was 1952 foot seconds and the striking energy was 13,223 foot tons. The projectile was a Carpenter 10-inch armor-piercing shell, No. 267 of lot 1, hardened to 0.5 inch below bourrelet, the weight of projectile being 500 pounds. The distance between gun and plate was 394 feet.

The plates were 6-inch face-hardened nickel steel plate B 525 and 5.5 inch nickel steel face-hardened plate B 504½, both supplied by the Carnegie Steel Company. The 5.5 inch plate was the port re-entrant plate which had been recently tested. The 6-inch plate had been previously used, 20 impacts for the tests of 6-inch armor-piercing projectiles having been made upon it. The 5½-inch plate was against the structure; the 6-inch plate was outside of it and toward the gun. They were lapped over each other for a distance of 4 feet 3 inches. No greater flat surface was available, previous impacts on the 6-inch plate interfering. The results obtained, however, show that this overlapping was ample for the experiment. The contact between the two plates was as good as can be looked for in actual practice. The 5.5-inch plate next the structure had its original backing of 3.5 inches of oak and 2½-inch skin plates, and was secured to the structure by three holding-in bolts. The 6-inch plate was secured against the 5½-inch plate by timbers and bolts passing through previous impacts and a vertical timber at the end where it overlapped the 5½-inch plate, thoroughly secured by bolts above and below. All the experts present agreed that the plates were well secured together.

The impact on the front or 6-inch plate was 4 feet 1½ inches from the bottom, 2 feet 5 inches from the left edge and 2 feet 8 inches from the nearest impact—that is, the impact was about the center of the superimposed portions of the plate. The angle of impact was normal. The projectile penetrated both plates, passed through about 15 inches of sand, and coming to the surface was thrown out to the right and found at a point 70 feet to the rear and 33 feet to the right of the point of impact. The point was broken off the projectile. The number of pieces found was five, the largest piece weighing 453.5 pounds; the total weight of pieces picked up, 459 pounds. The projectile was pronounced to be of fine quality.

Effect on Front Plate.—The projectile made a clean hole through the 6-inch plate, the diameter of the hole being 10⅜ inches. The interior surface was fused. The diameter of flaking was 14 inches; diameter of back bulge, 22 inches; the height of back bulge was 3 inches, ragged, and there was a front fringe of about 1 inch. A number of radial and circular cracks were developed about the point of impact. A small piece was broken out of the plate toward the nearest edge.

Effect on Rear Plate.—The projectile passed through the rear plate, making a cone-shaped hole 16 inches in diameter on the side nearest to gun, 13 inches in diameter on the side furthest from the gun. The plate was dished 2 inches. The back bulge was all broken away. A through crack went from the impact to the right edge of the plate and two concentric cracks about half way around on the left side of the hole 24 to 32 inches in diameter. The backing and skin plates were badly torn by fragments of plate.

The tests were made under the direction of Lieutenant-Commander Couden, who made the following brief report of the result to the Department: "Although a comparison is difficult to make, it would seem that

this combined plate was somewhat less resistant than a single plate of the same thickness. Both these plates are of most excellent quality. The 6-inch plate has received 20 impacts and demonstrated its high resisting power and excellent quality heretofore. The rear plate has shown its quality on this occasion."

All experts who witnessed the test unite in the opinion that the superimposed plates proved much less efficient than single plates of their combined thickness, made under similar conditions and heretofore tested under equivalent specifications.

A test was made at Bethlehem during the past week of the 10-inch face-hardened armor of the battle-ships Kentucky and Kearsarge. These plates are nickel steel, double forged, and the ballistic plate was backed by 12 inches of oak and 2½-inch skin plates. Three rounds were fired, with the following results:

First Round.—Eight-inch armor-piercing shell; striking velocity, 1476 foot seconds. Plate uncracked; projectile broke up, head remaining sticking in plate; estimated penetration, 2 inches.

Second Round.—Eight-inch Holtzer armor-piercing shell; striking velocity, 1752 foot seconds. Plate uncracked; projectile broke up, head remaining sticking in plate; estimated penetration, 3 inches.

Third Round (supplemental).—Eight-inch Holtzer armor-piercing shell; striking velocity, 2078 foot seconds. Plate uncracked; projectile broke up, head remaining sticking in plate; penetration unknown.

While the tests at Indian Head of the two thin plates can hardly be compared with those at Bethlehem of the 10-inch plate, yet in whatever relation exists between the two the superiority of the thick plate is claimed by experts to be clearly apparent.—*Iron Age.*

At the Indian Head Proving Grounds a charge of 300 pounds of gun-cotton was recently exploded between two ⅝-inch iron plates, which were parallel and fifty feet apart; one was 15 and the other 35 feet from the explosive. It was expected that the detonation would injure the plates, but it did not. A great hole, however, was blown into the ground. It seems to be settled that high explosives must be nearer than 15 feet to injure a ship.

Experiment with Gathmann Shell.

Experiments which the Bureau of Ordnance of the Navy have been making at the Indian Head Proving Grounds with a shell intended to permit the use of high explosives in ordinary guns came to a somewhat disastrous end on Wednesday, June 1, by the bursting of the shell in the gun, which in turn was torn to pieces with a tremendous explosion. The witnesses of the trial escaped unharmed, though pieces of the burst gun and shell fell around the tug upon which the ordnance officers were watching the test. The officer who discharged the gun escaped only because he had sheltered himself behind an embankment instead of resorting to the usual corner of the bomb-proof, where the force of the explosion was so great that it collapsed a small wooden building used to shelter the instruments. The shell was a Gathmann shell, loaded with over 300 pounds of gun-cotton, and it is supposed that it was made to withstand the shock of the explosion of the powder charge in the gun, which in this case was much less than usual, the pressure being about three tons instead of 15 tons to the square inch. The gun destroyed was

jacketed tube, intended for a 13-inch gun, but so far only bored out as a 12-inch tube. The ordnance officers have never been satisfied as to the possibility of using gun-cotton in this way, but made the experiment by direction of Congress, which set aside an appropriation for the purpose.

Test of Jovite in Projectiles, and of Corn Pith in Cofferdams.

Important information in regard to three features of naval ordnance and construction was obtained to-day, June 12, as a result of tests made at the Indian Head Proving Grounds.

In the first place the officials demonstrated that jovite, the new high explosive, when loaded in a service armor-piercing projectile, could be safely fired from a high power gun through Harveyized armor, and would explode in the rear of the target. For the first time since the adoption of semi-armor piercing shells in the navy, one of 10 inches in caliber was fired through a Harveyized plate, the thickness of which was slightly greater than half the shell's caliber, and exploded in the rear. In addition, the trials to-day showed the ability of corn pith when placed back of armor to keep out the water, provided the armor and structure behind it are not greatly overmatched by the penetrating projectile.

The tests were made as the result of a recommendation by Chief Naval Constructor Hichborn that two cofferdams, one protected by 4-inch armor and the other by 5½-inch armor, be tested in order to ascertain whether or not corn pith could be depended upon to prevent water from entering a ship through a shot hole.

The cofferdam protected by 4-inch armor was first fired at with a 6-inch capped armor-piercing projectile with a velocity of 1800 feet per second. It made a clean hole in the armor, perforated the entire structure and the butt ten feet in the rear, and was picked up seventy feet away in excellent condition. The size of the hole in the rear of the cofferdam was about ten inches, through which very little water escaped.

Then a six-inch armor-piercing projectile, containing jovite and fused, was fired at the target with a velocity of 1865 feet per second. It was desired by the authorities that the shell should explode in the cofferdam. The shell failed to do as anticipated, but perforated the target and exploded fifteen feet from the face of the target. This is the first time an armor-piercing projectile has been safely exploded, powder failing to take such action.

The men on duty at the proving grounds hunted for some of the pieces of the projectile, but were unsuccessful. This showed that the projectile had been blown into small pieces, and had it exploded on shipboard the result would have been disastrous. No cracks appeared in the armor.

After these two shots were fired a box-like arrangement fitted in front of the four-inch plate was closed and water poured in. It was found that the water leaked from the shot holes in the rear of the target at the rate of about sixteen gallons per minute.

Attention was then directed to the target protected by five and a half inch armor. A 10-inch semi-armor-piercing shell was loaded with eighteen pounds of black powder and fired at the target with a velocity of 1650 feet per second. The shell perforated the target, practically demolishing the rear of the cofferdam and exploded just on the edge of the butt. The hole in the rear of the cofferdam was about four feet in diameter. —*New York Herald.*

[ENGLAND.]

TRIAL OF VICKERS SIX-INCH ARMOR PLATE.

We have succeeded in obtaining the following authentic details of the remarkably successful trial of the Vickers plate tested on board the Nettle at Portsmouth on the 19th of March last. The dimensions of the plate were 8 feet by 6 feet by 6 inches. It contained among other elements, 4 per cent. of nickel. There was originally a hair line about the center of the plate. The mounting and backing were as usual, the thickness at the top and bottom was 4 feet 10 inches, and at the center 5 feet 10 inches. The plate was secured by eight bolts.

The attack was made entirely with 6-inch Holtzer armor-piercing steel projectiles, fired with a charge of 48 pounds of EXE powder, which gave a muzzle velocity of about 1960 foot seconds. The striking velocity was practically the same, the plate being fixed at only a few feet along the deck.

The first shot was delivered near the right-hand bottom corner. The projectile broke up, leaving the point embedded, and apparently fused into the plate. When the point was jarred out by the 6th shot the depth of indent was found to be 2¼ inches. There was slight scaling round the point of impact. At the back was a bulge 1⅜ inch high, and 12 inches by 12 inches in area, with one crack. There may be noticed on the face certain white radiating splashes. These always seem to indicate complete disintegration of the shot. In former days they furnished evidence that the attacking projectile had been of chilled iron; but latterly, since the faces of plates have been specially hardened, steel projectiles have sometimes broken up in such a way as to exhibit these splashes.

The second round was delivered near the left-hand bottom corner. The result closely resembled that of the first round. Apparently, judging from the front, a larger part of the shot's point was embedded. There is more scaling, but no splash. The shot, however, seems to have flattened more, the bulge at the back being only ¾ inch in height, and having no crack in it.

The third round struck towards the left top corner, the shot breaking up in much the same way as before. There was a little more scaling off of the surface, and a hair crack was developed from point 2 to the left of the plate. After the point of this shot jarred out, the depth of the injury was found to be 1¾ inches. The bulge at the back was 1 inch high and 13 inches by 13 inches across.

Round 4 struck the near right top corner. The general result was as before; the shot spread as much as 2, but more of the mass lodged probably, as the bulge at the back was 1⅛ inch high and 14 inches by 14 inches across. There was rather more scaling round the shot, and the hair crack from 2 was rather more developed.

Round 5 was delivered near the center. The effect was again much as before, the shot breaking up in the same way. It was after this round that the point of No. 3 was dislodged, leaving the rest of the lodged portion of the head in a ring round it. The bulge at the back was 1 inch high, and both its horizontal and vertical cross measurements 14 inches.

This completed the proof test, which had been most successful in all respects. At the request of Messrs. Vickers a sixth shot was planted in the plate between rounds 5, 2, and 1, that is, a little below the center. The same general effects were again produced, though they were rather

greater, the surface of the plate was "driven in locally," and local cracking produced with irregular scaling about 2 inches deep, forming a sort of crater between rounds 2 and 6. The point of No. 1 was jarred out by this shot. The bulge at the back was 1½ inches high, and measured across 13 inches and 14 inches, and there was a crack made. Altogether, the slightly increased effect of this round only shows what we well know, that the molecular action in the metal of the plate extends further than could be seen from inspection.

As to ballistic results, the velocity is not measured, but is approximately 1960. This implies a striking energy of about 2665 foot tons, and a perforation by Tresidder's formula of about 13.45 inches of iron, or 2.24 times the thickness of the actual plate. Supposing the plate to weigh 5.275 tons, which is what we calculate from its dimensions, the energy per ton of each blow is 505 foot tons, and the total of the six blows 3030 foot tons per ton. This shows a more severe test than plates of this thickness have been hitherto subjected to. On these thin plates the shock of resisting strain never comes to a large amount, on account of their area being large in proportion to their thickness, but, as pointed out in the case of the Cammell and Brown plates similarly tried, the perforation attack defeated, works out very high. We wish, however, in order to enable a complete comparison to be made with foreign plates, one or more Wheeler-Sterling projectiles could be fired in our Nettle tests. As they are now supplied by Elswick, this might be easily done. We would conclude by congratulating first Messrs. Vickers, and then not only our three Sheffield makers, but England as a nation, on the excellence of the 6-inch plates now being delivered. This Vickers plate we are specially glad to describe, because it had an extra round fired at it, and is a singularly excellent plate.—*The Engineer.*

SHIPS OF WAR.

[United States.]

Trial of U. S. S. Iowa.

The U. S. battle-ship Iowa, constructed by the Messrs. Cramps, at Philadelphia, was given her official trial in Long Island Sound over the Cape Ann course on April 6, the weather conditions being most favorable. The stations were 6.6 miles apart, and the course was thirty-three miles north-northeast from the first station, about five miles southeast of Thatcher's Island to the sixth station, about a mile to the eastward of Boone Island buoy and return. The elapsed time for the first half was 1:57:23. Average speed, 16.873 knots; for second half, 1:55:24; average speed, 17.27. Average speed for the entire distance, 17 knots; elapsed time, 3:52:47.

The official speed as subsequently reported by the trial board, with all allowances for tides and other interfering conditions, was 17.871 knots.

The boilers showed an average pressure of 152 pounds, all that could be expected with the inch of air pressure allowed in the closed fire-rooms. Both engines ran with remarkable uniformity, the revolutions of the screws not falling below 111 per minute nor rising above 113½, and averaging 112 for the run.

The speed was also remarkably uniform between the several marks along the course, and shows that the vessel scarcely made any spurts, but kept close to her best work all the time, the variations being almost wholly due to the changing depth of the water.

After the trial her turning powers were tried. She answered her helm readily, and showed the possibility of turning a circle of less than 400 yards. She was also very steady in trimming, and her greatest angle of heel was only two degrees. The absence of vibration, even when the ship was driven at her highest speed, was very marked. In fact, the vibration could hardly be felt except at the extreme bow and stern.

Holland Submarine Boat.

The Holland submarine torpedo-boat was launched successfully from the yards of Mr. Lewis Nixon, at Elizabethport, N. J., on May 17.

The boat was towed into the adjoining slip, where she will remain until her private trial trip, after which she will be sent to Washington.

The date of her private trial trip has not been made public. An official public test will be made soon, Mr. Holland said, when an engineer officer from each government will be allowed on board. Mr. Holland, speaking of his boat just launched, was quoted as follows:

"The craft is 53 feet 3 inches long, with a diameter of 10 feet 3 inches amidships, a 4-foot screw protecting extension, and the moulded diameter is 10 feet 3 inches. She can travel under water 8 hours at 8 knots, and 10 knots on the surface. It will take barely one minute to submerge the boat, and not much longer to raise it to the surface of the water.

"The armament consists of three torpedo-tubes, one at the upper bow of the boat being an aerial torpedo thrower, with a range of one mile. Six projectiles weighing 180 pounds, with charges of 100 pounds of explosives, are to be stored for this gun.

"Almost directly beneath the torpedo-thrower is an expulsion tube for Whitehead torpedoes. Only three of these torpedoes will be carried, as each one weighs 850 pounds. At the stern of the boat is a submarine gun which, with a 100-pound charge of explosive, can hurl a 400-pound projectile 100 yards or more under the water. Five of these projectiles will be carried. The craft will be worked by six men.

"Now, I have this boat and one somewhat similar, which is being built at Baltimore. The latter boat is much longer than this one, and for that one reason more interest is centered in it."

TRIAL TRIPS OF GUNBOATS.

The Wilmington and Helena.

The gunboat Wilmington, built by the Newport News Shipbuilding & Dry Dock Company, made a very successful trial trip on March 27. The course was in Long Island Sound, from Horton's Point to Cornfield lightship and return, a distance of twice 27 knots. She drew 8 feet 2 inches forward and 9 feet 1 inch aft. The engines made a mean of 267 revolutions per minute; the maximum was 277. Steam pressure was 189 pounds. The contract speed was to be 13 knots, but she made 15.07 knots, earning a bonus of $41,512.

The Helena eclipsed the performance of the Wilmington, making the official speed of 15.49 knots per hour. She carried 180 pounds of steam and her engines made an average of 279 revolutions on the official run.

The Annapolis.

The new gunboat Annapolis, which is the first to be completed of the six composite hull boats ordered by the Government early in 1896, was given its official trial of four hours at full speed on Long Island Sound on April 22. This gunboat is notable as being the first U. S. Government vessel of large size to be fitted with boilers of the water-tube type exclusively. Other vessels have been built within a few years in which the Scotch type and the water-tube boilers have both been used in connection with each other.

The Annapolis was built at the Crescent Ship Yard, Louis Nixon, Manager, Elizabethport, N. J., and the boilers were furnished by the Babcock & Wilcox Co. of New York City, whose works are also at Elizabethport. The same type of boiler has also been adopted for the gunboat Marietta.

In this boiler the water tubes are all straight, placed at an angle of 15° with the horizontal, and expanded at each end into forged steel headers. Openings are provided in these headers opposite the ends of the tubes, through which a thorough examination of each tube may be made, and the tubes cleaned and renewed when necessary. By means of a steam jet inserted between the headers all deposits of soot may be removed from the exterior of the tubes. Surmounting the sections of tubes is a steam and water drum 42 inches diameter and 10 feet long; all openings leading into and out of drum are 4 inches diameter. Steam to 200 pounds pressure can be raised from cold water in half an hour, this being a most important feature in boilers for a war-ship. The boilers are designed for a working pressure of 250 pounds.

The principal dimensions of the Annapolis and of its steam equipment are as follows:

Length, 204 feet; width, 36 feet; depth, 23 feet 3½ inches; displacement on a draft of 12 feet, 1000 tons; boilers, two, each 94 square feet of grate and 3600 square feet of heating surface; ratio of grate to heating surface, 1 to 38.3; engine, triple expansion, with cylinders 15, 24½ and 40 inches diameter, 28 inches stroke; contract speed of vessel, 12 knots with 800 IHP. The builder's trial showed that 900 IHP could be developed under natural draft, with a short funnel.

On the official trial forced draft in the ash pit was used, each boiler being supplied by air from independent Sturtevant fans, the average air pressure in the ash pit being limited to 1 inch of water.

During the 4-hour trial the steam pressure averaged 226 pounds per square inch, the minimum being 218 and the maximum 240 pounds. The draft pressure in the ash pit averaged 0.90 inch on the port side and 0.91 inch on the starboard side. The speed trial over a measured course of 48 knots, marked by nine stake boats, gave a speed in the eight divisions of the course ranging from 12.7 to 14.18 knots per hour, averaging 13.43 knots.

The maximum IHP developed by the main engine was 1400, the average being 1320, at 147 revolutions per minute. The collective IHP will average about 1360. Dividing 1320 IHP into 3600 square feet heating surface gives one IHP for each 2.73 sq. ft. of heating surface. Dividing it by 94 square feet of grate gives 14 IHP per square feet of grate. During the test under forced draft the smokestack did not become hot enough to burn the paint off it.

At the end of the test of four hours at full speed the helm was put hard to port and to starboard without reducing speed, and the little vessel made circles with a diameter of 400 feet. In turning she heeled only 3.5 degrees.

THE NASHVILLE.

The new light-draft United States gunboat Nashville made her official trial on Long Island Sound on May 4, and earned for her builders, the Newport News Shipbuilding and Dry Dock Company, a bonus of near $60,000, her speed greatly exceeding that which was guaranteed, and for which the Government will reward her constructors. Her average speed throughout her trip was 16.7 knots, while but 14 knots was required. The course was laid from Stratford Light to Horton's Point, a distance of 30 miles in a straight line, and return. There were six stake boats, consisting of the tugs Leyden and Narkeeta, the lighthouse tender Cactus, and the torpedo-boats Stiletto, Porter, and Ericsson, which were anchored at distances of five miles along the course. The total time consumed in the run was three hours and forty-seven minutes. After the speed test the gunboat was put through several tests to show her seaworthiness, all of which were successful.

The Nashville is schooner-rigged, and is interesting because of her peculiar machinery arrangements. She has twin screws and two sets of quadruple expansion engines. The cylinders of these are arranged in fore and aft lines, with the low pressures towards the bow. The purpose is to disconnect these big cylinders by a shaft coupling when the vessel is on ordinary cruises, making the engines triple expansion, and as thus arranged they can be worked with small consumption of coal at about eight knots speed. By coupling the low-pressure cylinders with the others the speed may be run up to fourteen knots, though at the expense of much more coal. At cruising speeds an economy closely approximate to that of careful merchant steamers is expected. Her smoke-pipes are very tall, reaching almost to the top of her masts.

Aside from these novel machinery arrangements, the features of the Nashville are as follows: Length, 220 feet; breadth, 38 feet 3 inches; displacement, 1371 tons; complement, 150 men; battery, four rapid-fire 4-inch rifles on the main deck, four of the same in armored sponsons on the gun deck, four 6-pounder Hotchkiss guns and a number of 1-pounder and Gatling guns.—*Seaboard.*

THE WHEELING.

The official trial trip of the gunboat Wheeling took place on Saturday, May 29, on a twelve-mile course in San Francisco bay. She ran four hours at 231.4 revolutions a minute, with a steam pressure of 180 pounds, giving a speed of 12.75 knots per hour. Her working was entirely satisfactory, less coal per horse-power being required than by her sister ship, the Marietta, and the engine and fire-rooms were cooler.

THE VICKSBURG.

The gunboat Vicksburg, sister ship of the Newport, had her official trial trip on May 29 off Bath, Me., and developed a speed of 12.68 knots an hour, which is about four-tenths of a knot better than the Newport made over the same course.

Trial Trips of the Porter.

The torpedo-boat Porter withstood a very severe test June 10, with the Board of Inspection and Survey on board of her, running her final trial before acceptance by the Government. She started at six o'clock in the morning from the foot of East Twenty-sixth street and returned to the same wharf at half-past six o'clock in the evening, having steamed around Long Island in twelve and one-half hours. She averaged about twenty knots for the run and varied from fifteen to thirty knots speed in both rough and smooth water.

Probably no other torpedo-boat ever had such a severe test, and certainly the Porter came through it splendidly, for she clearly demonstrated that she could make much more speed than she was contracted to make. This trial, however, was not for speed, and the steam pressure was limited to 200 pounds, instead of the 225 pounds that her boilers may carry.

She also demonstrated that her water-tube boilers can steam with salt water in them, though it was thought not advisable to carry more than one hundred pounds of steam under these circumstances.

Following are the particulars of her run: At six o'clock she left the wharf under one boiler, making fifteen knots up the East river, under the auxiliary stop valves. The Porter has two sets of stop valves, the main valve being a twelve-inch and the auxiliary stop being one and a half inches in diameter. At forty-four minutes past six she connected a second boiler, and for a time made twenty knots with 160 pounds of steam and one-quarter of an inch of air pressure forced draught.

At ten minutes past eight she opened the main stops and made twenty-five knots, with one inch of air pressure and 150 pounds of steam.

At half-past nine she connected the third boiler, and for fifty minutes, between Stratford Shoal and Falkner's, made thirty knots, with 200 pounds of steam and one inch of air pressure.

At the end of another fifty minutes, being out of sight of suitable ranges to get the actual speed for an hour, one boiler was cut out, and the Porter proceeded through Plum Gut and around Montauk Point at twenty-one knots, heading for Sandy Hook Lightship at half-past eleven, with Montauk light abeam.

A stiff breeze was blowing, with quite a heavy sea and white-caps.

To Fire Island she averaged eighteen knots, when a leak was developed in the main feed pipe which could not be controlled, so that all the fresh water was lost, and the vessel was obliged to drop to one boiler and use salt water therein, in addition to the evaporators and distillers.

The leak having been repaired, the Porter left the navy yard at seven o'clock, June 11, to complete the final trial for acceptance. She first went over to Communipaw for a small supply of coal, and at nine o'clock went alongside the dock at East Twenty-sixth street, where the Board of Inspection and Survey boarded her. She then steamed down to the lower bay, where the tests took place. These tests were eminently satisfactory.

All the torpedo-tubes were tested, torpedoes being successfully fired from each of the three tubes at a boat sent out from the Porter as a target. The turning circle of the Porter was determined with both engines going ahead at full speed, making seventeen knots, with the helm hard over. The diameter of her circle under these conditions was found to be about 1000 feet, a very small area for such speed.

Then the little boat squared away, and while going ahead at seventeen knots the engines were suddenly reversed. She stopped almost instantly, and was going full speed astern before she had gone one-half her length. Then the experiment was reversed, and the result astonished even those who have served in her since her commission. The little craft shook herself, stopped, and went ahead in less than one-quarter of her own length.

The time necessary to shift the helm by steam, from hard a-port to hard a-starboard, and the reverse, while going ahead at full speed, was found to be six seconds, and the same time is required for the return to hard a-port.

It was noted with curiosity that the Porter heels toward the center of her turning circle when the helm is put over. Other steam craft heel the other way under similar conditions. The hand-steering gear was tested from both forward and aft and found to be most satisfactory.

During the entire run of the day only one boiler was in use, and that one was the boiler in which salt water had been used during the Porter's run around Long Island on Thursday. This boiler worked well, and a careful examination shows no bad effects resulting from the use of the salt water.—*New York Herald.*

[CHILI.]

THE O'HIGGINS.

The Chilian cruiser O'Higgins was launched from the yard of Sir W. G. Armstrong, Whitworth & Co., Elswick, on May 17. The vessel is named after an Irishman who was the founder of the Chilian Navy, and ex-President Admiral Montt spoke of him also as the founder of the republic. The principal dimensions of the cruiser are: Length, 412 feet; breadth, 62 feet 9 inches; mean draft, 22 feet; displacement, 8500 tons. Her armament will consist of four 8-inch, ten 6-inch, four 4.7-inch, ten 12-pounders, ten 6-pounder quick-firing guns, four machine-guns, and three torpedo-tubes. The total coal capacity is 1200 tons, and the guaranteed speed is 21¼ knots.—*United Service Gazette.*

[ENGLAND.]

THE EUROPA.

H. M. S. Europa was launched March 20 at the Clydebank Shipbuilding Company's works. She is a first-class cruiser of the Diadem class, of 11,000 tons displacement, 435 feet length, 69 feet beam, and 25 feet 3 inches mean draft. Two sets of triple-expansion engines to develop 12,500 I. H. P. at natural draft, 16,500 with forced draft, giving a maximum speed of 21 knots. Coal capacity 1000 tons at normal draft; total capacity, 2000 tons. These vessels carry batteries of sixteen 6-inch and fourteen 12-pdr. R. F. guns, besides 12 3-pdrs. and numerous machine-guns. There are four funnels and two military masts.

THE PYRAMUS.

H. M. third-class cruiser Pyramus, of Pelorus type, was successfully floated out of the Jarrow dock on May 15.

Launches and Trial Trips of Destroyers.

The destroyer Chamois, on May 7, during her full speed preliminary run, maintained for three hours a mean speed of 30.336 knots with 386 revolutions per minute.

The Whiting, on her official trial, May 10, maintained for three hours a mean speed of 30.167 knots with 392.7 revolutions per minute. At the latter portion of the trial, when the tide was stronger and the boat had become somewhat lighter, a speed of 32.8 knots was attained.

The Earnest, on her official trial, May 24, maintain for three hours a mean speed of 30.12 knots.

The Griffon, on her three hours' coal consumption trial on May 25, maintained 30.02 knots. On her full-power trials, June 1, six runs over the measured mile resulted in a mean speed of 30.12 knots.

The Flirt was launched at Jarrow, May 22, and the Wolf at Birkenhead, June 2.

The Turbinia.

A further series of trials of the torpedo-boat Turbinia began on April 9th by Professor Ewing, F. R. S., and concluded on Wednesday, April 14th. The full speed trials were taken on Saturday, when the mean speed of 32¾ knots on the measured mile was realized. On several of the days the sea was rough, but throughout there was no perceptible racing of the screws, and the engines worked with perfect smoothness and a complete absence of vibration. On Wednesday the 14th the turning and circling tests were satisfactorily carried out, and a test for acceleration showed that the boat could be started from rest to 28½ knots speed in 20 seconds and brought to rest from this speed in 35 seconds.—*Engineering.*

[France.]

The Jena.

The dockyard authorities at Brest have received orders to proceed with the construction of the new battle-ship, designated in the estimates as A3, which is to be called the Jena. She will be laid down on the slip from which the Gaulois was launched last autumn, and will be the largest ship yet built at this yard. She will be somewhat larger than the Gaulois and her sisters, the Charlemagne and St. Louis, as the following comparison between the dimensions of the ships will show:

	Jena.	Gaulois.
Length	396 feet 9 inches.	385 feet 6 inches.
Beam	67 feet 3 inches.	66 feet 6 inches.
Maximum draft	27 feet 6 inches.	27 feet 6 inches.
Displacement	12,052 tons.	11,275 tons.
Speed	18 knots.	18 knots.
Maximum I. H. P.	15,500.	14,500
Normal coal storage	820 tons.	677 tons.
Radius of action at 10 knots	5200 miles.	4500 miles.

The ship will have three screws, steam being provided by twenty Belleville boilers, which will be fitted to burn either coal or petroleum. If necessary, the ship will be able to carry 1100 tons of coal, which will give her an extra radius of action of 1800 miles, or 7000 miles in all. Protection will be afforded by a complete water-line armor belt, with light

armor over the other works, and two armored decks, but the thickness of the armor has not yet been settled. The armament will consist of four 30.5-centimeter (12-inch) guns, in two turrets, one forward and one aft; in a central battery between the turrets will be eight 16-centimeter (6.3-inch) Q. F. guns, four firing from the beam to right ahead, and the other four from right astern to abeam; above, on the superstructure, will be eight 10-centimeter (3.9-inch) Q. F. guns similarly disposed for the end-on to beam fire; there will also be sixteen 3-pounder, five 1.5-pounder Q. F. guns, and thirteen 1-inch magazine guns, with six torpedo-tubes.

Lavoisier.

The third-class cruiser Lavoisier was launched at Rochefort on 18th April; her dimensions are as follows: Length, 326 feet 8 inches; beam, 35 feet 8 inches, with a displacement of 2300 tons. Her engines are to develop 6600 I. H. P., and her estimated speed will be 20 knots. Her armament is to consist of four 14-centimeter (5.5-inch), six 10-centimeter (3.9-inch), eight 3-pounder, and six 1-pounder guns, all Q. F., with four torpedo-tubes.—*Journal of Royal United Service Institution.*

[Germany.]

The Victoria Luise and the Hertha.

The second-class cruiser L was launched March 29 at the works of the Weser Company, and was christened Victoria Luise. The sister ship, K, christened Hertha, was launched April 14 at the Vulcan dockyard, Stettin. The third vessel of this class, Ersatz Freya, is still on the ways.

These cruisers are built entirely of steel, 344 feet long, 57 feet extreme beam, with a mean draft of 20½ feet and a displacement of 5650 tons. They are driven by three screws, the three separate engines giving a total of 10,000 indicated horse-power, capable of producing a speed of 18½ knots. The coal capacity is 500 tons at normal draft. The armament will consist of two 8.2-inch Q. F. guns, one forward and one aft in 4-inch armored hooded barbettes, eight 6-inch Q. F. guns, four on the main deck in 4-inch armored casemates, two with an arc of training from right ahead to 35° abaft the beam, and two with an arc of training from right astern to 35° before the beam, and the other four on the upper deck. Also in armored casemates ten 3.4-inch Q. F. guns (20-pounders), ten 3-pounder Q. F. guns, and four machine-guns with three submerged torpedo-tubes, one in the stern and one on each beam. There is a 4-inch armored deck, and the heavier guns have separate armored ammunition tubes, all the armor being of Krupp's nickel-hardened steel. The total complement will be 439 officers and men.

Station Cruiser G.

The new station cruiser G is to be built at the Germania yard at Kiel, which was lately taken over by the Krupp firm at Essen. Like the earlier fourth-class cruisers, the new vessel is intended for foreign service, but it is is of an improved type, her dimensions being as follows: Length, 325 feet; beam, 36 feet; mean draft, 14 feet, with a displacement of about 2600 tons. The hull will be of steel, wood sheathed; there will be a two-inch armored deck and an armored conning tower. The

engines are to develop 6000 I. H. P., giving a speed of 20 knots. It is proposed to lay down four vessels of this type as soon as the money can be voted for them.

[ITALY.]

ST. BON.

The battle-ship St. Bon, named after Admiral St. Bon, was successfully launched on May 29th. She is a sister ship of the Emanuele Filiberto and was built at the Royal Dockyard at Venice. Her principal dimensions are as follows: Length, 345 feet; breadth, 70 feet; mean draft, 24 feet 9 inches; displacement, 9800 tons. The two sets of vertical triple expansion engines were built by the Ansaldo firm, and with 13,500 indicated horse-power will give a speed of 18 knots. There are 12 cylindric boilers with 36 furnaces. The total coal capacity is 1000 tons, given a steaming radius of 7500 miles at 10 knots; besides this, liquid fuel can be carried in the double bottoms. There is a complete armor belt along the water-line of Terni nickel steel plates varying in thickness from 4 to 9.8 inches, the armor of the redoubt and barbettes 9.8 inches; the battery is protected by 5.9 inches. The armament consists of four 10-inch breech-loading rifles, two in the forward barbette and two aft, eight 6-inch R. F. guns in the redoubt, each gun being further protected by steel splinter bulkheads, eight 4.7-inch R. F. guns, also six 57 mm. guns, as well as numerous rapid-fire guns of smaller caliber. All these guns were built at the Armstrong establishment at Pozzuoli and at the Spezia arsenal. There are one stem and four broadside torpedo-tubes. The complement will be six hundred men and officers. In launching this ship the custom of breaking a bottle of wine over the bows was departed from. The Crown Princess Helen followed an old Venetian custom, securing to the ship a gilded bronze ring about 5½ inches diameter, engraved with a suitable inscription, by means of a silk ribbon of such a length that during the launching this ring would touch the water first. The ring will be preserved in the Royal Arsenal.

AUXILIARY CRUISERS.

The following-named vessels are destined as auxiliary cruisers in case of war: The Nord America, length, 445 feet; displacement, 4826 tons; Vittoria, length, 400 feet; 4300 tons; 4500 indicated horse-power; Duca di Galliera and Duchessa di Genova of the Veloce Company; the Regina Margherita, length, 375 feet, 4000 tons, 3687 indicated horse-power; Elettrico, Candia and Malta, all of the Company Navigozione générale. The vessels are each to be armed with light rapid-fire batteries.

[JAPAN.]

TRIALS OF THE FUJI.

The battle-ship Fuji, built at the Thames Ironworks, on her first trials of six hours' steaming, averaged 16.937 knots with 10,200 indicated horse-power. The later trials for full speed gave a mean speed of 18.655 knots with 14,100 horse-power, the vessel being down to her deep-load draft. The steering gear, supplied by Davis & Co., enabled the helm to be put from hard-over to hard-over in 16 seconds.

The Latest Japanese Battle-ship.

Within the past two months the Thames Ironworks and Shipbuilding Company have contracted to build for the Imperial Japanese Government a still larger and more powerful battle-ship than the Fuji, a vessel, in fact, which in her offensive and defensive powers will constitute one of the most formidable armor-clads yet constructed for any navy.

As the displacement of the largest armor-clads of the British Navy—those of the Majestic class—when fully equipped, but without their coal—900 tons—on board is only 14,000 tons, the new Japanese vessel, which is to have a displacement of 14,850 tons, with a coal capacity of 700, will have 150 tons more weight in her hull than any of the battle-ships of the class mentioned.

The dimensions of the new vessel are to be: Length between perpendiculars, 400 feet; over all, 438 feet; breadth, 75 feet 6 inches; water draft, 27 feet 3 inches, and displacement as given above, viz., 14,850 tons. She will be constructed on the double-bottomed system, with water-tight flats at her ends, practically making her double-bottomed throughout. Her side protection will consist of a lower armor belt, made of Harveyed nickel steel, carried from stem to stern, 8 feet 2 inches deep, and 9 inches thick throughout the length of the engine, boiler and magazine spaces, tapering to 4 inches at the ends. Above the lower armor belt, and for a length of 250 feet amidships—which length encloses the two barbettes for the big guns—an additional belt of 6-inch armor is to be worked to the height of the main deck. Rising from the lower edge of the main armor belt to a height on the middle line of the ship of about 3 feet above the water-line, and extending from stem to stern, there will be a complete armor deck of steel 3 inches thick on the flat part and 5 inches on the slopes, tapering at the ends. From this deck, and at either end of the 250 feet armor belt, which forms the sides of and is equal to the length of the citadel, the two barbettes, which are to be circular in form and protected by 14-inch armor, rise through the main deck, and continue to a height of 4 feet above the upper deck. A curved thwartships bulkhead of steel 14 inches thick will be worked from above the protective deck to the height of the main deck, and between the main and upper decks steel screen bulkheads will also be fitted, extending from the barbettes to the ship's sides.

The armament of the new battle-ship will consist of four 12-inch 40-caliber breech-loading guns, two being in the forward and two in the after barbette; fourteen 6-inch 40-caliber quick-firing guns in armored casemates of 6-inch Harveyed nickel steel, eight being on the main deck and six on the upper deck, the casemates being made water-tight on their inner and outer sides, thus serving to protect the gun crews from explosive shells entering between decks, and preventing water finding its way there should a gun port become damaged. Supplementing the above detailed armament there are to be twenty 12-pounder quick-firing guns placed on the upper deck, eight 47-millimeter guns on the upper and main decks and military tops, and four similar sized guns on the bridges. There will also be fitted five 18-inch torpedo ejectors, one in the stem above water and four submerged, the usual torpedo-nets completing the defensive gear.

The steering of the vessel will be effected by steering gear, on Cameron's self-regulating principle, worked by steam-steering engines in duplicate, as a preventive in case of the possible failure of one set, the

controlling gear being on Messrs. Brown's telemotor principle, controlling the helm from pilot house, forward bridge, after pilot house and bridge, and from the protective deck forward.

The propelling machinery of the new ship, which will be of 14,500 indicated horse-power, will consist of two complete sets—in separate engine-rooms—of three-cylinder triple-expansion twin-screw engines, the diameters of the cylinders being 34 inches, 53 inches, and 84 inches for high, intermediate, and low pressure respectively, with a piston stroke of 48 inches. They will be supplied with steam by twenty-five of the latest type of Belleville boilers, having an aggregate heating surface of 40,000 square feet.

The ship will be lighted throughout by electricity, the installation consisting of four sets of combined engines and dynamos—three of 400 ampères and 80 volts each and one of 200 ampères and 80 volts, the latter of the direct current type. Nine hundred incandescent lamps of 16-candle power each will be provided for lighting saloons and cabins, store, engine, and boiler-rooms, magazines and coal bunkers, etc. Six search-lights, each of 20,000 candle-power, having mirrors 24 inches in diameter, will also be provided.

The complement of boats carried by the new battle-ships will be fourteen, and will include two 50-feet vedette boats, fitted with the Thames Ironworks water-tube boilers; one 42-foot launch, and one 30-foot steam pinnace, each of which will carry Whitehead torpedoes, and be fitted for mining and countermining.

The ship will have a complement of men and officers to the number of 741, which will include an admiral and thirty-eight officers. The contract time for the completion of the vessel has been fixed at twenty-seven months.—*Engineer.*

The Japanese Government have entered into a contract with Messrs. Yarrow & Co., Limited, of Poplar, for the construction of four torpedo-boat destroyers of 31 knots speed.

[NORWAY.]

TORDENSKJOLD.

From the Walker shipyard of Sir W. G. Armstrong, Whitworth & Co., there was launched on the 18th of March, for the Norwegian navy, the armor-clad ship Tordenskjold. The vessel is a sister ship of the Harald Harfaagre, which was launched on January 4 last from the same yard. There is an armor belt 7 inches to 4 inches in thickness; the conning tower is protected with 6-inch armor plate, and she has a ram. The armament, differing somewhat from that of her sister ship, will consist of two 8-inch quick-firing guns, six 4.7-inch quick-firing guns, six 12-pounder quick-firing guns, and six 1½-pounder quick-firing guns.

[RUSSIA.]

Great activity continues to reign in all the Russian dockyards. At Nicolaieff, a second-class battle-ship, a sister ship to the Rotislav and Sissoi Velikie, of 8800 tons displacement, has been laid down. In addition, two first-class battle-ships of 12,480 tons are to be commenced, of which one is to be ready for launching next year, and the second in 1900.

The construction of the battle-ships Poltava, Petropavlovsk and Sevastopol, each of 10,960 tons, is rapidly approaching completion, and the armored coast-defense vessels Apraxin, of 4126 tons, and the gunboat Khrabry, of 1500 tons, will be shortly ready for sea.

At the New Admiralty Dockyard, St. Petersburg, the squadron battle-ship Osliaba, of 12,840 tons, 14,500 horse-power, and 15.5 knots; the first-class cruiser Aurora, of 6630 tons, 12,000 horse-power, and 21 knots, are nearly ready; the gunboat Gilyak, of 810 tons, and an armored coast-defense vessel of 4126 tons and 5250 horse-power, are building. At the Galierny Ostrov, the ocean cruisers Diana and Pallada, each of 6630 tons, 12,000 horse-power, and 21 knots. At the Baltic Works, the squadron battle-ship Pereswiet, of 12,480 tons, 14,500 horse-power; in France, the cruiser Svetlana, of 3828 tons, 9000 horse-power, and 20 knots. Besides the aforementioned vessels, there are also building in the Baltic two torpedo-cruisers to be named Abrek and X, and fifteen torpedo-boats.

The old armored battery Netronj-Menia is to receive new boilers and be fitted for petroleum fuel. Two new sea-going torpedo-boats, Nos. 133 and 134, have completed their trials off Cronstadt; they averaged a speed of 24.5 knots, and are fitted with Du Temple water-tube boilers. These boats are two out of ten constructed by the Moscow Company on the Neva; two other larger boats, 180 feet long, have been ordered at the Creighton Works at Abo. Further experiments with the Masut (a petroleum mixture) fuel have been carried out in the first-class torpedo-boat Viborg, and as a result all torpedo-boats fitted with locomotive boilers are to be fitted to consume this fuel. Torpedo-boats with water-tube boilers have not as yet been so fitted, but in all the new boats the necessary arrangements are to be made.

The new first-class battle-ship Tri Sviatitelia has undergone her twelve hours' full speed trial, which was completely successful. The engines worked smoothly throughout, developing considerably more than the contract horse-power, and gave the ship a speed of 18 knots instead of 16, for which the vessel was designed. The engines were built by Messrs. Humphrys, Tennant & Co., of Deptford, who have built the engines for so many of the Russian ships.

[SPAIN.]

OSADA.

The Clydebank Engineering and Shipbuilding Company, Limited, on March 16 launched a twin-screw torpedo-boat destroyer named the Osado, constructed for the Spanish Government. The Clydebank Company some time ago received orders to build for the Spanish Government a number of vessels of this class, and recently they delivered the Furor and Terror, after they had gone through speed trials very satisfactorily. The vessel now launched will be similar to the Furor and Terror, and will carry the same armament, but the tonnage will be somewhat greater, and she is to steam two knots faster. While resembling in appearance the destroyers built at Clydebank for the British Government, these vessels have some necessary modifications in arrangements and fittings, principally with the view to making them suitable for service in very hot climates.—*Engineering.*

THE NEW CRUISER RIO DE LA PLATA.

The Spanish residents of Rio De La Plata have determined as a token of their loyalty to and love for their mother country to present the

Spanish Government with a ship-of-war. Her name is to be Rio De La Plata, and she is to be built at the Forges et Chantiers Works. She is to be a cruiser of 1750 tons displacement, to make a speed of 16½ knots natural draft and 21 knots with forced draft. The triple-expansion engines to develop 7100 horse-power, steam to be furnished by four Normand boilers. The coal capacity of 270 tons to give a steaming radius of four thousand sea miles at 12½ knots speed. The protective deck to have a thickness of .4 inch thick on top and .8 on the sides. The vessel is to have two masts with fighting tops, a steel conning tower, a sharp ram, to be provided with three search-lights and full electric lighting plant. The armament to consist of Hontoria guns, viz.: Two 6-inch, four 4.7-inch, six 57 mm. rapid-fire guns, besides two 37 mm. Hotchkiss revolving guns, four 25 mm. machine-guns and two fieldpieces. There will be two torpedo-tubes and six torpedoes.—*Diario de Cadiz.*

The Cristobal Colon.

This armored cruiser of 6840 tons, built by Ansaldo firm of Genoa, had her trial trips on the 27th and 28th of April. With natural draft, and with 98 to 100 revolutions, she made an average speed of 19.56 knots per hour. During the sixth hour coal consumption trial, during which she made a speed of 18½ knots, the consumption of coal was 1.62 pounds per horse-power per hour.—*Le Yacht.*

Maxim Guns for the Navy.

The latest model of the seven mm. Maxim machine-gun is to be generally introduced into the Spanish Navy. The armored cruiser Carlos V is to be at once supplied with these guns.

[Sweden.]

A New Submarine Boat.

Engineer Nordenfeldt has built a new submarine torpedo-boat, the preliminary trial trips of which both at the surface and at a depth of 30 feet were begun a short time ago. The boat is cigar shape, has a length of 65 feet and a maximum diameter of nearly 12 feet. The motive power is steam, the diving apparatus is automatic. The crew will consist of three men. Trial trips of one hundred and fifty miles will be made between Stockholm and Gothenburg.—*Le Yacht.*

BOOK NOTICES AND REVIEWS.

MAHAN'S LIFE OF NELSON.

In view of the many excellent reviews of this latest work of Captain A. T. Mahan, U. S. Navy, which have appeared at home and abroad, the following one, taken at random, and which appeared in the *Spectator* of April 17, 1897, is republished:

"This is a book which is so great, great in so many ways, that as one closes it one almost fears to review, lest one should be tempted to use language that will rather mar the effect which its own charm and its own power ought to exercise on the independent mind of every reader. What we should like to do is simply to convince every one that they ought to read it for themselves, with no fears that they will not be able to understand every line of it, and that they should then freely form their own judgment upon it. That Captain Mahan is able to write of naval warfare in such style and with such clearness as to make it easily intelligible to every landsman, is well known to all those who have read his fascinating volumes on "The Influence of Sea Power on History." The capacity which he shows in this work for pure biography, for bringing out in all its light and shades one of the most striking characters in all history, has not been disclosed before. The "Life of Admiral Farragut" was a much simpler effort. Each of his works has shown a growing strength, both in its literary style and in the confidence with which he lays down principles, works out a solid basis of fact from conflicting evidence, and draws from his facts deductions of permanent value.

The moral problems with which he has to deal in this book are of wider human application than even those great political and statesmanlike questions which both in this and in his former works, have in his lucid exposition been handled in such a manner as to influence the decisions of kingdoms and empires, and materially to affect the relations of the Great Powers of Europe. As a biography of a great man of action it seems to us to have no rival. Captain Mahan's enthusiasm for Nelson the hero, the great sea-captain, the devoted self-sacrificing subject of the English crown, never leads him into doing injustice to those whom Nelson wronged, never for a moment makes him swerve from his clear perception of Nelson's violations of the moral law. That is much. But that which is far more striking is that he never for a moment assumes that tone of patronising superiority which, when the lapses of his hero occur, it is so hard to avoid without seeming to approve that which it would be most dangerous that he should not condemn. Whether in dealing with Nelson's treatment of his wife, with the execution of Caraccioli, with his relations to Sir William and Lady Hamilton, or with such relatively less important matters as his not infrequent acts of wilfulness, the soundness and healthiness of the tone of the biographer is a most marked characteristic. Much material has come into Captain Mahan's hands which was not available for Nelson's earlier biographers. This chiefly affects the delicate ques-

tion of his domestic relationships. Unhappily, its whole tendency is to make the case of Nelson's conduct in the matter of Sir William and Lady Hamilton look distinctly blacker than it had done before. Many of us had previously doubted whether Horatia, though she was most certainly Nelson's child, might not have been the daughter of some other woman than Lady Hamilton. Captain Mahan appears to have shown conclusively that the doubts on this point had been only due to an elaborate system of mystification devised by Nelson, not merely for the protection of Lady Hamilton's reputation, but in order to conceal the betrayal of Sir William under circumstances peculiarly disgraceful to him as a man, and contrary to all his own strongest sentiments of honor.

"However great was Nelson's infatuation," says Sir Harris Nicolas, "his nice sense of honor, his feelings of propriety, and his love of truth were unquestionable. Hence, though during a long separation from his wife on public service in the Mediterranean, he so far yielded to temptation as to become the father of a child, it is nevertheless difficult to believe that he should for years have had criminal intercourse with the wife of a man of his own rank, whom he considered as his dearest friend, who placed the greatest confidence in his honor and virtue, and in whose house he was living. Still more difficult is it to believe, even if this had been the case, that he should not only have permitted every one of his relations, male and female—his wife, his father, his brothers, his brothers-in-law, his two sisters and all their daughters—to visit and correspond with her; have ostentatiously and frequently written and spoken of her virtuous and religious character, holding her up as an example to his family; have appointed her the sole guardian of his child; have avowedly intended to make her his wife; have acted upon every occasion as if the purity of their intimacy was altogether free from suspicions; and in the last written act of his life have solemnly called upon his country to reward and support her. An honorable and conscientious man rarely acts thus toward his mistress. Moreover, Nelson's most intimate friends, including the Earl of St. Vincent, who called them a pair of 'sentimental fools,' Dr. Scott, his chaplain, and Mr. Haslewood were of the same opinion, and Southey says 'there is no reason to believe that this most unfortunate attachment was criminal.'"

That quotation from Nicolas sets forth fully the reasons why many of us had perhaps partly allowed the "wish to be father to the thought" that Horatia's mother might not have been Lady Hamilton. Alas! the evidence which Captain Mahan has produced appears to show conclusively that that hope and that wish were a dream. As he puts it—

"This complicated and difficult path of deception had to be trod, because the offence was not one of common error, readily pardoned if discovered, but because the man betrayed, whatever his faults otherwise, had shown both the culprits unbounded confidence and kindness, and upon the woman, at least, had been led by his love to confer a benefit which neither should have forgotten."

And yet with wonderful power Captain Mahan has made the life consistent with the character of a man singularly noble and generous, the most ready of all men to devote his whole life and all his energies to the service of his country, and has shown how the "breadth and acuteness of Nelson's intellect have been too much overlooked in the admiration excited by his unusually grand moral endowments of resolution, dash, and fearlessness of responsibility. . . . In this contrast, of the exaltation of the hero and the patriot with the degradation of the man, lie the tragedy and the misery of Nelson's story."

Nevertheless, taken as a whole, the life is an inspiring one, and its grander qualities can no more be obscured by the one great lapse than is the story of Bathsheba able to destroy the inspiration of David's genius and devotion. Only the strange part of the matter is that the very strength of Nelson's character and his self-confidence made him never feel a shadow of regret or repentance, so far as any outward indications appear, and did not in the least, so far as can be judged, affect that intense religious feeling and absolute sense of trust in the Most High with which he went into all the greater actions of his life, or even his daily dependence in ordinary concerns upon Almighty protection. On the whole, we think that in the matter of the execution of Caraccioli Captain Mahan has cleared Nelson from the graver stains which have been supposed to be attached to the act. He thinks, and we believe rightly, that Nelson was legitimately entitled, under the circumstances, to break the convention with the Neapolitan rebels, the convention having been made without his authority, and no advantage having been taken of it, before it was repudiated, to put them in a worse position than they had been in before it was made. The influence of Lady Hamilton does not appear to have been exerted in the matter. The great objection to his conduct in ordering the trial and prompt execution is that "it stands conspicuous as the act of an English officer imbued with the spirit of a Bourbon official." He was acting at the moment under the authority of the King of Naples in the latter capacity; but it was impossible that the world should distinguish between the British admiral and the Neapolitan King's vicegerent.

That Captain Mahan's volumes should be full of valuable suggestions in regard to many questions that are of importance at the present time, especially as to the bearing of the question of naval supremacy upon the possibilities of the invasion of England and of the best forms which her defense can assume, was to be fully expected from his previous record. He has, in fact, dealt with a fire and vigor which leave nothing to be desired, with a large number of questions which have been lately discussed. He is as firmly convinced as we that Napoleon did distinctly intend, at the time of the Boulogne camp, to carry out the invasion of England, and that he only desisted from the attempt because he had been baffled by the superior skill, seamanship, and audacity of the English sailors against his own admirals. Without going into details, which would be here impossible, we may say that the general effect of Captain Mahan's contention is very strongly to bring out the necessity of a defense by land as well as sea. Moreover, the art with which he has made most interesting those periods of Nelson's work, during which it was his patience, his resource, and the vitalizing energy with which he infected all under him that were conspicuous, rather than skill or daring in battle, is especially effective in this, that it brings out better than it has ever done before how all-important was the co-operation of sea and land forces for the full use of that power of which Nelson was the embodiment. Captain Mahan has an almost Shakesperian tendency to drop as he goes along wise reflections, pithy sentences, gnomoe, many of which are, apart from their context, of almost universal application in the affairs of life. Often they are highly polished, always wholesome, and not infrequently very weighty.

Altogether it is a great biography, and one to be read by all men, whether they know much or little of previous attempts at the portrayal of our greatest sailor and most patriotic Englishman."

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MAY 1. Tribute to a Hero. Usefulness of Naval Militia.

MAY 8. The Torpedo-boat Porter. The Army: Its Employment in Time of Peace.

MAY 15. Russet Leather Horse Equipments. The Brooklyn Dry Docks.

MAY 22. Firing Regulations Revised. The Army; Its Employment in Time of Peace.

MAY 29. Army Small-Arms Firing Regulations. The Government is too Poor.

JUNE 5. The Army; Its Employment in Time of Peace. Army Firing Regulations.

JUNE 12. Marines at Ships' Guns. The Army; Its Employment in Time of Peace.

JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS.

MAY, 1897. The Construction, Installation and Performance of the Electric Lighting Plant at the Government Hospital for the Insane at Washington, D. C. Contract Trial of the Gresham. Experiments with an Air-Lubricated Journal. The Design and Testing of Centrifugal Fans. On Crank Shafts. The Contract Trials of the U. S. Gunboats Helena and Wilmington. The Application of the Compound Steam Turbine to the Purpose of Marine Propulsion.

JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES.

APRIL, 1897. The Use of Electric Motors in Machine Shops. European Boiler Practice.

AMERICAN ELECTRICIAN.

APRIL, 1897. The Insulation of Armature Cores. Thermo-Electric Batteries. Interior Wiring. Fly-Wheel Governors. Calculation of Wiring.

MAY. Dynamo Characteristics. Electric Pumping Construction of a Galvanometer. Interior Wiring. Steam Engine Economics. Lessons in Practical Electricity.

JUNE. A Modern American Central Station. Central Station of Rouen, France. Central Station of Brighton, England. Multiple Expansion Engines and the Cost Account. Drop in Alternating Current Lines. The Economics of Power Transmission.

ELECTRICAL ENGINEERING.

JUNE 1, 1897. Some Notes on the Manufacture of Incandescent Lamps. Higher Mathematics.

THE UNITED SERVICE.

MARCH, 1897. The Siege of Hamburg. His Last Appearance. Depreciators of the Nation. The Yacht Gnome. Conversational Arithmetic. The Soldier's Leisure Hours in a Western Army Post.

APRIL. Washington as a Soldier. The Indian Mutiny in Fiction. The Yacht Gnome (continued). Conversational Arithmetic (continued).

JOURNAL OF THE U. S. CAVALRY ASSOCIATION.

MARCH, 1897. Work of the Cavalry in Protecting Yellowstone National Park. Horse-shoeing. The Shelter Tent. Campaigning in Arizona and New Mexico, 1895-6. Device for Loading and Unloading Cavalry Horses in Movements by Rail. Notes on Feeding Cavalry Horses.

ENGINEERING NEWS AND AMERICAN RAILWAY JOURNAL.

APRIL 15, 1897. Compressed Air for Blowing Fog Signals.

MAY 20. The Frames of the Friedrich (illustrated). Leaks in the Brooklyn Dry Docks.

THE ENGINEER.

APRIL 10, 1897. The Rotary Steam Engine. Corrosion and Scale from Feed Waters. Heating Feed Water by Exhaust Steam.

APRIL 24. Marine Propulsion in the Past. The Steam Turbine. Spontaneous Combustion of Coal.

MAY 22. Coaling War-ships at Sea. The Manufacture of Guns in the United States. Official Trials of the Helena and Wilmington.

JUNE 5. Experiment in Boiler Bracing.

JOURNAL OF THE MILITARY SERVICE INSTITUTION.

MAY, 1897. Proper Military Instruction. The Present Status of Field Artillery. Ammunition Supply in Foreign Armies. Proposed Uniform Examinations. A Sketching Board.

JOURNAL OF THE UNITED STATES ARTILLERY.

No. 25, MARCH-APRIL, 1897. Field Shrapnel and the Cannon of the Present. Some Notes on our Artillery Target Practice. An Improved Method of Hauling Heavy Guns. The Progressive Development of the Schools for Artillery Practice in Germany. An Experiment with Militia in Heavy Artillery Work. Report on Development of a Photo Retardograph.

THE IRON AGE.

APRIL 22, 1897. A Year's Shipwrecks. The Armor Question.

MAY 6. Profits on Armor Plate Manufacture. Armor Plate Negotiations.

MAY 20. Iron Fortifications (illustrated). A Recent Bethlehem Plate (illustrated). The Light House Establishment. Petroleum Fuel for Vessels.

MAY 27. The Manufacture of the Colt Navy Revolver, Model 1895.

SCIENTIFIC AMERICAN.

APRIL 10, 1897. First-class Battle-ship Iowa. Patents of Naval Officers.

APRIL 17. No Bids for Armor Plate. The Battle-ship Iowa.

MAY 1. Nickel Steel Armor. Large Shipment of Army Cannon.

MAY 8. Naval Parade, Grant Monument Dedication. The Fastest Vessel Afloat.

MAY 22. Brooklyn Navy Yard Dry Dock Leak. Inventor of the Automatic Gun. Gun Manufacture in the United States. Brooklyn Navy Yard Dry Dock Leak. Mast Arm Electric Lamp.

JUNE 5. Improved Rapid-fire Guns.

JUNE 19. Two New Atlantic Steamships. Great Steamships' Engines. Oiling Ships' Hulls. The Torpedo-boat Porter.

CASSIER'S MAGAZINE.

JUNE, 1897. Steam and Hydraulic Steering Gears. The Evolution of the British Coasting Steamer.

SEABOARD.

APRIL 1, 1897. Speed of Gunboats Wilmington and Helena. Description of Gunboats.

APRIL 8 and 15. Senator Elkins' Speech for Discriminating Duties. Bonus on the Iowa.

APRIL 22. Senator Elkins' Speech (continued). Official Report on the Trial of the New Gunboats.

APRIL 29. Senator Elkins' Speech (continued).

[FOREIGN.]

JOURNAL OF THE ROYAL UNITED SERVICE INSTITUTION.

APRIL, 1897. The Relative Advantages of Voluntary and Compulsory Service, both from a Military and a National Point of View. Shorthand in the Army. Swiss Regiments à l'étranger. The Construction and Working of Belleville Boilers. The First Forcing of the Khaibar Pass, 1838-39. Naval and Military Notes.

MAY. The Relative Advantages and Disadvantages of Volun-

tary and Compulsory Service, both from a Military and a National Point of View. The National Study of Military History. Obok and the Country Bordering on the Gulf of Tajura.

PROCEEDINGS OF THE ROYAL ARTILLERY INSTITUTION.

APRIL, 1897. The British Army in the Continent of Europe. Coast Defense.

MAY. The Science of Frontier Delimitation. Direct and Indirect Fire. Encampments in Hill Warfare on the N. W. Frontier of India.

ENGINEERING.

MARCH 26, 1897. The U. S. Battle-ship Alabama (illustrated). Manning the Navy. The Prevention of the Vibration in Steamships. The Stevens Battery (illustrated).

APRIL 2. New Battle-ship for the Japanese Navy (illustrated). The Growth of a Japanese Steamship Company. The Prevention of the Vibration of Steamships. Maxim's Testing Apparatus for Smokeless Powder (illustrated).

APRIL 9. Dry-Back Marine Boiler (illustrated). Ascertaining the Stability of Ships (illustrated). Apparatus for Measuring Stellar Photographs (illustrated). Water-tube Boilers in Warships.

APRIL 16. British Sailors and British Ships. Re-arming the Older Ironclads. The Steam Turbine and Marine Propulsion (illustrated). Designing Ship's Lines. The Accelerity Diagram of the Steam Engine (illustrated).

APRIL 23. The U. S. S. Terror and the Pneumatic System as Applied to the Guns, Turrets and Rudder (illustrated). The Hotchkiss Automatic Gun (illustrated). Automatic Machine Guns.

APRIL 30. Rapson's Slide as Applied to the Steering of Large Ships. Nickel Steel (illustrated).

MAY 7. Lyall's Water-tube Boiler (illustrated). The Accident to H. M. S. Star.

MAY 21. The Rocket.

JUNE 4. Petroleum as Steam Engine Fuel (illustrated). Rotary vs. Reciprocating Marine Engines (illustrated).

THE ENGINEER.

MARCH 26, 1897. Canal Communication from the Midlands to the Sea (illustrated). Some Great Liners. The New Japanese Battle-ships (illustrated). The Chilian Cruiser Esmeralda (illustrated).

APRIL 2. Aluminum: Its Present and Future, No. 1. The Alabama and the Prince George (illustrated). Behr Lightning Express Railway Carriage. Hamburg-American Liners Pennsylvania and Arabia (illustrated). Marine Propulsion in the Past. The latest Japanese Battle-ship.

APRIL 9. Water-tube Boilers in War-ships. The Steering Gear of the Japanese Battle-ship Fuji (illustrated). Recent Trials of the Cruisers Powerful and Terrible. Mechanical Method of Ascertaining Stability of Ships. British and Foreign Armor and Shot.

APRIL 16. On the Fighting Value of Certain of the Older Ironclads if Re-armed. Sims-Dudley Powder-Pneumatic Gun (illustrated). Hotchkiss Automatic Machine Gun Trial. Navy Boilers. The Use of the Mean Water-Line in Designing the Line of Ships. The Application of the Compound Steam Turbine to the Purpose of Marine Propulsion.

APRIL 23. Aluminum: Its Present and Future, No. 2. Recent Developments in Mercantile Ship Construction. The Cruiser Brooklyn, United States Navy (illustrated). Woolwich Arsenal. H. M. S. Swordfish and Spitfire (illustrated).

APRIL 30. Harvey Nickel Plate Trials (illustrated). Steam Pinnaces for the Admiralty. The French Submarine Cable-Laying and Repairing Steamer Portena (illustrated).

MAY 7. Recent Developments in Mercantile Ship Construction, No. 2. Army Signaling and its Use in War. A New Chronograph (illustrated). Submarine Telegraphy during War (illustrated). The Augusta Victoria (illustrated). Bigler's Signal Buoy (illustrated).

MAY 21. Aluminum: Its Present and Future, No. 3. The Steamship La Grande Duchesse (illustrated).

MAY 28. Aluminum: Its Present and Future, No. 4. Water-tube Boilers in the Mercantile Marine.

JUNE 4. The Naval Section of the Victorian Exhibition, Crystal Palace. The Birkenhead Destroyers. The French Navy.

MORSKOI SBORNIK.

MARCH, 1897. Discussion of Problems in Naval Tactics. Classification of Fighting Ships. Notes on Ordnance and Armor. Trial of the Machinery of the English Cruiser Terrible. The Dalnometer (range-finder). Meteorology as the Science of Wind Vortices.

Professional Notes: Naval Strength of Foreign Fleets in Cretan Waters. Launches of the English Cruisers Niobe and Doris. Shipbuilding Programmes, England and France.

APRIL. Discussion of Problems in Naval Tactics. Outline of English Landing Expeditions. The United States Navy, 1895-

96. The Price of Armor (Report of the Secretary of the U. S. Navy). Determinate of Astronomical Base in Nova Zembla. Note upon Stoppage of Leaks in the Iron-clad Admiral Greig.

Professional Notes: English Shipbuilding in 1896. English Naval Budget, 1897. Trial of the Jauréguiberry. Spanish Torpedo-boat Destroyers Terror and Furor. A New Portuguese Cruiser. J. B. B.

ANNALEN DER HYDROGRAPHIE UND MARITIMEN METEOROLOGIE.

No. III, 1897. Hydrographic Remarks on the Chusan Archipelago, Woosung, and Mouth of the Yantse. Oil for Quieting the Sea. Determination of Geographic Positions on Land without the Use of Astronomical Instruments.

No. IV. Report on Drift Ice in the Indian Ocean. Mistpoeffers.

Investigation of the mysterious sounds or reports occurring along the Flemish and Dutch coasts, as well as in the interior, especially on sunny days, and designated mist-poeffers.

Hydrographic Researches in the Red Sea.

APPENDIX I. Middle Distances of Steamer Routes in Sea Miles.

The table gives distances between the principal ports of the world, alphabetically arranged.

MILITÄR WOCHENBLATT.

NOS. 22 TO 28, MARCH, 1897. The Attack and Defense of Constantinople from the Land Side. Condition of Greek Navy.

NO. 30. American Pneumatic Guns. Effectiveness of Small Calibered Rifles.

NO. 32. Increase of French Navy.

NO. 37. Military and Naval Manœuvres, 1897, in Austria.

NO. 39. English Field Piece of Mounted Batteries.

DEUTSCHE HEERESZEITUNG.

NO. 20, MARCH 13, 1897. The Gunners of Lissa Island.

In memory of the heroic defense of the island by the Austrian artillerymen against the attacking Italian fleet, July 18, 19 and 20, 1866.

Trafalgar and To-day (continued).

NOS. 21 AND 22. Trafalgar and To-day (concluded). Italy's Naval Shipbuilding.

The following ships are under construction, time of completion 1897 to 1899: First-class battle-ship Admiral St. Bon, building at Venice, 345 feet long, 69 feet beam, 13,500 horse-power. The sister ship, Emanuel Philibert, is building at Castellamare di Stabia. Second-class battle-ships

Joseph Garibaldi and Varese, the former at Sestri Ponente, the latter at Leghorn, are of 6840 tons displacement, 13,000 horse-power, 330 feet long, 60 feet beam, armed with two 10-inch, ten 6-inch, and six 4.7-inch guns. The Victor Pisani, at Castellamare, of 6500 tons, 325 feet long, 59 feet beam, armed with twelve 6-inch, six 4.7-inch guns and two launching tubes. The Agordat and Coatit, at Castellamare, are 6th class vessels, of 7000 horse-power, 287 feet long, 31 feet beam, armed with four 4.7-inch, eight 57-millimeters and two 37-millimeters rapid-fire guns and 2 launching tubes. A torpedo destroyer, at Sestre Ponenti, of usual Italian type.

No. 23. The First German Torpedo-boat Destroyer.

Nos. 25 and 26. Vessels of the German Navy to be Launched in 1897.

Five, possibly six, ships-of-war will be launched in Germany during the present year. The second-class cruisers K, L and Ersatz Freya will be ready in the spring.

These cruisers are of 6000 tons displacement, and correspond to cruisers 1st class of other navies. They will be fitted with cork coffer-dams, three separate engines, water-tube boilers, liquid fuel arrangements, and batteries of rapid-fire guns. The batteries will consist of two 21-cm. guns, one forward, one aft, in revolving turrets, four 15-cm. guns in turrets and four in casemates, ten 8.7-cm., ten 3.7-cm. guns and eight .8-cm. machine-guns.

The other vessels are the armored cruiser Ersatz Leipzig and the battle-ship Ersatz Friedrich der Grosse. The Leipzig is of 10,650 tons displacement, to make 20 knots with 15,000 horse-power. The battery consists of rapid-fire guns, viz. four 24-cm. 40-caliber guns in revolving turrets, twelve 15-cm. and ten 8.7-cm. guns, ten 3.7-cm. machine-guns, and eight Maxims.

The battle-ship of 11,000 tons, three engines, triple screw; armor-belt thickness up to 30 cm.; battery of four 24-cm. guns in barbettes, eighteen 15-cm., twelve 8.7-cm., twenty-four 5-cm. guns, twelve 3.7-cm. machine-guns and some Maxims, making a total armament of 78 guns.

On the Four Panama Canals and their Influence upon Ocean Lines of the World.

No. 27. Shipbuilding Program in the Reichstag for 1897.

Nos. 31 to 37. Modern Artillery Problems Viewed from a Tactical Standpoint. The New German Cruisers.

No. 37. The Squadrons of the Powers in the East Mediterranean in April, 1897. The Italian Cei Rifle.

Nos. 38 and 39. Reorganization of the Technical Troops.

MITTHEILUNGEN AUS DEM GEBIETE DES SEEWESENS.

Vol. XXV, No. 5, 1897. The English Fleet Manœuvres, 1896. Zanzibar. The Turbinia. Foreign Navies.

No. 6. The New Rules of the Road at Sea. Tests of Face-hardened Nickel-steel Armor Plates.

Test of an 8-inch Creusot plate intended for the turrets of the Danish

battle-ship Skjold, and test of two Italian 6-inch plates manufactured at Terni.

England's Naval Budget, 1897 to '98. Foreign Navies.

MARINE RUNDSCHAU.

APRIL, 1897. History of the Fleet (continued). Lack of Cruisers and Utility of Cruisers. Two Episodes of the year 1798: 1, Weakness of Nelson's Fleet in Cruisers in his Pursuit of Bonaparte to Egypt; 2, The Importance of Cruisers in the Destruction of Commodore Bompart's Expedition in 1798. Floating the Grounded Russian Cruiser Rossija. Plans for the Rapid and Efficient Ventilation of Coal-bunkers without Removal of Bunker Plates. The Austrian Torpedo-cruiser Magnet, Cheops, Osakku, Jeddo.

MAY. History of the Fleet (continued). Fighting Values of the Navies of the World. A New Invention for Utilizing the Forces of Waves and Tides. The Murman coast. German Mythology in Connection with the Names given to recent German Naval Vessels. Naval Notes.

JUNE. History of the Fleet (continued). The Struggle for the East Asiatic Trade. Activity of the "Zieten." France's Sea Fishery and its Connection with l'Inscription Maritime. Upstarts in the German Sailor Language. Naval Notes.

H. G. D.

UNITED SERVICE GAZETTE.

MARCH 27, 1897. French Aspirations to Sea Power. Our Naval Resources in Time of War.

APRIL 3. The Education and Training of Naval and Military Cadets. The Influence of Public Opinion on the Navy.

MAY 15. The Entry of Naval Cadets. The Development of the Torpedo-boat.

MAY 29. The Navy and the Country.

JUNE 5. Our Proposed Standard of Naval Strength.

THE STEAMSHIP.

APRIL, 1897. The Navy Estimates, 1897-98. The New Japanese Battle-ships (illustrated). Liquid Fuel (illustrated). Harrison's Noiseless Steering Engines (illustrated).

MAY. Estimation of the Power of Steamships at Sea. A Mechanical Method of Ascertaining the Statical Stability of Ships (illustrated).

JUNE. Martin's Ship's Light Indicator (illustrated). Institute of Marine Engineers. Launch of Two British War-ships. New Method of Propelling Steamers (illustrated).

JOURNAL AND PROCEEDINGS OF THE UNITED SERVICE INSTITUTION OF NEW SOUTH WALES, 1896.

Reminiscences of the Chitral Campaign. Railways in Warfare. High Explosives and Field Fortifications.

LE YACHT.

MARCH 6, 1897. The Use of Turbines as Motors. The Battle-ship Masséna.

The Masséna, built by the Ateliers et Chantiers de la Loire, upon plans furnished by M. de Bussy, former naval inspector, has been carefully designed both as to armament and protection. Its speed of 17 knots is considered amply sufficient for a battle-ship. Its radius of action is that pertaining to that class of vessels. Its principal characteristics are: Length, 112.65 m.; breadth, 28.31 m.; draft, aft, 8.16 m.; displacement, 11,924 tons; normal horse-power, 9200; guaranteed speed with natural draft, 17 knots.

Its armament consists of 2 guns of 305 mm., 2 of 274 mm., 8 of 138.6 mm., all in closed turrets of the Creusot manufacture. There are besides in the superstructures 8 guns of 100 mm., protected by simple shields, with numerous 47 and 37 mm. guns. The calibers 138 mm. and under are quick-firing. The 305 mm. and 274 mm. are placed, the first in the axis of the vessel, the second on the sides about amidships, each in a separate closed turret 40 cm. thick in the rotating part and 35 cm. in the fixed part down to the protective deck. The turrets are worked by hydraulic power of the Creusot system. The big guns are provided with the Farcot breech block. The 138 mm. guns are 45 calibers long. The dispositions of the batteries are such that it can fire at once 11 guns, either forward or aft, and the same number broadsides.

The Masséna has 4 torpedo tubes, 2 below water and 2 above. The steel hull is double the whole length of the ship, and carefully divided into water-tight compartments. There is no projecting keel.

Two side or bilge keels of teak wood lined over with galvanized sheets 45 cm. wide extend over a part of the ship and contribute to the platform stability. The stem of forged steel has the sharp, slender shape of the cruisers of the Bussy types, favorable to speed, and free the heavy waves forward when going at a rapid rate. The stern-post of cast steel. The armor protection is ample, representing 4000 tons in a 12,000 ton displacement, or one-third the total weight. Above the protective deck extends a continuous line of cofferdams with an outer light plating called the cofferdam plate. Floatability thus seems secured in nearly every case incident to battle. The vitals are protected against the action of powerful explosives, first by the belt of cofferdams, which will cause them to burst outward, and then by the splinter screen deck in case of portions of the main deck being broken off. In short, in regard to the composition and distribution of its armament, the Masséna is decidedly an improvement upon all former constructions and has no superior in any navy.

MARCH 13. The Fleets of Greece and Turkey. The Coast-defense Vessel Amiral Tréhouart.

MARCH 20. The Navy Estimates in the French Senate.

MARCH 27. The English Naval Budget.

APRIL 3. The Duration of Acceptance Trials in France.

APRIL 10. The Harbor of Bizerta.

APRIL 17. The Appropriation for the New Constructions.

The composition of the fighting units in the programme before Parliament to be carried out between now and 1905 is as follows: 6 battleships, 22 cruisers, 7 despatch or station gunboats, 35 despatch torpedo-boats or destroyers, and 150 sea-going or coast defense torpedo-boats.

APRIL 24. The Graeco-Turkish War on the Seas. The Decimal Time (Hour).

MAY 1. The Accident on Board the Russian Battle-ship Sissoï-Veliky.

MAY 9. Stability and Floatability during Battle. The Prince George.

MAY 15. Orientation of the Submarine Boat, with Reference to the Enemy.

Considers the various means of locating the enemy's vessel from an approaching submarine boat. The optical tube with mirrors; the periscope of Major Daudenart, which takes instantaneous photographs, all present objectionable features. Mirrors become dimmed, they are visible from afar, for their use the boat must be near the surface. The simplest plan and best under these circumstances is to rise to the surface and use the direct vision through the air.

If close to the enemy, the conditions are different, and the best means of steering for him are yet to be solved. Lateral submerged mirrors, capable of adjustment from the interior of the boat, are suggested. The use of oil is advocated for calming the sea above. Visibility under water is under most favorable circumstances very limited. Results of Mr. Herman Fol's experiments are quoted. As a last resort is suggested a means of locating the exact position by a sounding apparatus, used in connection with the depth registering apparatus, and a chart of the waters operated in, giving in minute details the depths and hydrographic features, so that the boat can feel its way along in the dark, as it were.

Trials of the Turbinia.

MAY 22. Germany's Naval Strategy. The Spanish Cruiser Cristobal Colon.

Gives full description with two illustrations.

Merchant Marine.

MAY 29. Propositions of M. Lockroy with Reference to Naval Program. Industrial Progress of the Arsenals. J. L.

REVUE MARITIME.

JANUARY, 1897. Geometry of the Diagrams. Medical Service on Board in Action. Development and Progress of the German Navy. A Note on the Use of Torpedo-boats.

FEBRUARY. A Memoir: Delivery of Toulon to the English in 1793. Aerial Currents; their Courses, and their Utilization by

Aerostats. The Atmometer, "an ingenious device for measuring evaporation."

MARCH. Geometry of Naval Tactics. Study of Budget Specialties. Air Currents, their Direction and Utilization. Method of Indicating Courses Steered at Night by a Steamer.

APRIL. Reports on Macassar collected by the Duguay-Trouin. Air Currents (continued). Study of Budget Specialties (concluded). J. L.

LE MONITEUR DE LA FLOTTE.

MARCH 6, 1897. The Crisis in the Merchant Navy.

Statistics show that for several years past the sea commerce of France has been steadily declining. Time and again laws have been enacted in Congress to check the evil, but they have been powerless in arresting the downward movement.

In 1881 a system of premiums to construction and navigation was established; but the law only covered a period of ten years, and although continued with slight modifications up to the present time, it failed in its ends, owing to the uncertainty of its provisions. The consequences are that the French ship-yards, once so active and prosperous, are now nearly deserted; ship-owners finding it to their advantage to buy their vessels in foreign countries, principally in England.

MARCH 13. Naval Programs.

In 1891, M. Barbey, then Minister of Marine, presented a program which was at first favorably viewed by Congress. But the following year the naval committee cut down the appropriation, and the result of this dilatory policy has been that an extraordinary effort is now made necessary in order to return the navy to its proper standard. If the program of 1891 had been carried out in its integrity, the government would have built or put on the stocks since January 1892 50 fighting units, exclusive of torpedo-boats. Actually it can only reckon on 35, or 15 units less than proposed, to wit: 3 battle-ships, 6 armored cruisers, 6 torpedo-catchers or destroyers, etc. Hence the reason for the enormous appropriation asked for this year for new constructions. It has been decided in the new naval program that the actual, whether afloat or building, shall be increased by 220 new fighting units of various types: 6 battle-ships, 22 cruisers, 7 despatch or station gun-vessels, 35 despatch torpedo-boats or destroyers, and 150 sea-going or coast defense torpedo-boats, construction to begin at once and to be pushed rapidly to obtain the needed units. Eighty millions of francs over and above the yearly appropriation are thus to be distributed over a period of eight years.

APRIL 17. The Composition of the Fleet.

The promulgation of the new naval construction could not fail to awaken, and has as a matter of fact revived in all its bitterness the smouldering discussions and polemics touching the respective value of the units composing a modern fleet. The scoffers and revilers of the armored battle-ship have resumed their criticisms of what they call derisively the "Mastodons" and "Cathedrals" of the sea; once more they have denounced the "folly," the "stupidity" of those who assume that given

certain circumstances, the battle-ship is a weapon of war of no mean value. They proclaim that the cruiser answers every purpose, and should therefore enter alone in the composition of a fleet. On the other hand they have purposely avoided mentioning the tonnage of the cruiser of their choice. Shall it be a large cruiser or a medium size one? Will it be a heavily armored cruiser, a protected cruiser, or simply a commerce destroyer (pirate-cruiser)? They are studiously vague on this, a most important point. It is no part of the discussions of these gentlemen to enter into details, to follow closely the data of the problems. Their rallying cry is, "Death to the Mastodons, fatal only to their own crews." They will not listen to other arguments, and after proclaiming the exclusive use in the navy of high speed vessels with great radius of action, they feel confident they have proved their case. What is gall to the champions of the cruiser, what is beyond their comprehension, is that the new building program should contain a proviso for the immediate construction of six battle-ships. They seem to lose sight of the fact that the Triple Alliance have numerous battle-ships afloat and are building many more. They also forget that victory must belong to the one whose power of resistance is most enduring. They make a great ado about end-on attacks in which light plates will offer as much resistance as thick plates. Yet nothing is more problematic than such theory. . . On the other hand, is has been advanced that the monitor (sea-going monitor) might probably supersede with advantage the ordinary type of the modern battle-ship. Such a vessel would possess some striking analogy with the ship designed by M. Bertin, in course of construction at Cherbourg, and named Henri IV.

MAY 8. The Composition of the Fleet, III. J. L.

REVUE DU CERCLE MILITAIRE.

FEBRUARY 27, 1897. Projected Tactics Regulations for the Russian Infantry. French Military Arts at the Brussels Exposition of 1897. An Historical Account of the Madagascar Expedition.

MARCH 6. The Niger Hydrographic Mission. An Historical Account of the Madagascar Expedition (continued).

MARCH 13. Probable Lines of Operations in the Event of a Conflict between the Franco-Russian Alliance and the Triple Alliance.

A very interesting study.

MARCH 20. The History of the Military Folding Bicycle. An Account of the Expedition to the Island of Madagascar (with photographs).

MARCH 27. Preparatory Military Instruction. A Pocket Field Glass.

APRIL 3. An Expedition into the Heart of Africa. Preparatory Military Instruction (continued).

APRIL 10. The Madagascar Expedition.

APRIL 17. Field Artillery Tactics.

MAY 1. Military Shelter Cabins in the Swiss Alps.

MAY 8 AND 15. The Irish Brigade in the French Service. German Warfare in East Africa.

MAY 22 AND 29. German Warfare in East Africa (continued). The Landside Defense of Constantinople. Entrance Examinations to Naval School in 1897. J. L.

SOCIÉTÉ DES INGENIEURS CIVILS.

JANUARY, 1897. A Study of a Type of Navy Marine Boiler.

The boiler must present the following characteristics: 1st, Strong with a least liability to explosion. 2nd, Sufficiently low built to allow of its installation under the armored decks, and compact, in order to take as little space as possible in all directions. 3rd, Capable of supplying at a given moment a considerable quantity of dry steam. 4th, Moderately light so as to permit a greater stowage of fuel and ammunition and an increase of armor protection. 5th, Capable of sustaining without risks the most sudden changes in the rate of steaming. 6th, Easy for handling and repairing with the means on board. 7th, Ready at the shortest notice in cases of emergency, and so constructed that spare pieces may be taken on board. 8th, Saving in fuel. 9th, Moderate in cost.

FEBRUARY. A French Expedition in a Balloon to the North Pole, by M. Surcouf. An Essay on the Determination of the Form of Least Resistance to the Motion of the Submarine Boat.

MARCH. Railroad from Senegal to the Niger. The Manufacture and Industrial Uses of Ozone. J. L.

REVISTA TECNOLOGICO INDUSTRIAL.

FEBRUARY, 1897. A Note on the Starting of a Train and a Means of Facilitating the Operation.

MARCH. Electrical Transmission in Industrial Establishments.

APRIL. The Engines and Boilers of the Emperador Carlos V. (with two plates). Electrical Transmission in Industrial Establishments.

REVISTA MARITIMA BRAZILEIRA.

MARCH, 1897. The Knowledge of a Naval Officer.

La Marine Militaire published some time ago an article under the *nom de plume* of Jean de la Poulaine, in which the writer pretends to prove that of all naval officers of the European or North American navies, the English are the most deficient in general knowledge. This assertion is based, it must be understood, upon the insufficiency of the scientific education received by the cadets on board the Britannia, and later, as midshipmen on board men-of-war.

APRIL. Organization of the Brazilian Navy. The Obry Apparatus for Regulating Torpedoes. Problems in Naval Strategy.

RIVISTA DI ARTIGLIERIA E GENIO.

APRIL, 1897. Firing Tables. The Defensive System of the Tyrol. Hotchkiss Automatic Gun. New Artillery Firing Instructions. Miscellaneous Notes.

MAY. The Rifle which does not Kill. Effects of Bullets from Small-calibered Rifles. The Theorem of Least Stress Applied to the Shrinkage of Gun Hoops. How to Compare Firing Exercises, Infantry and Artillery. Carrier Pigeons for Military Uses. Theory of Coast Artillery. Regulating the Fire of a Battery. Miscellaneous Notes.

BOLETIN DEL CENTRO NAVAL.

FEBRUARY AND MARCH, 1897. Spontaneous Combustion of Coal Aboard Ships. Official Inspection of the Squadron and Report of the Board. Brief Points on Modern Naval Warfare (continued). New Victory of Gun over Armor. Naval Ordnance in Connection with Old and Modern Powders.

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SPECIAL NOTICE.

NAVAL INSTITUTE PRIZE ESSAY, 1898.

A prize of one hundred dollars, with a gold medal, is offered by the Naval Institute for the best essay presented on any subject pertaining to the naval profession, subject to the following rules:

1. The award for the prize shall be made by the Board of Control, voting by ballot and without knowledge of the names of the competitors.

2. Each competitor to send his essay in a sealed envelope to the Secretary and Treasurer on or before January 1, 1898. The name of the writer shall not be given in this envelope, but instead thereof a motto. Accompanying the essay a separate sealed envelope will be sent to the Secretary and Treasurer, with the motto on the outside and writer's name and motto inside. This envelope is not to be opened until after the decision of the Board.

3. The successful essay to be published in the Proceedings of the Institute; and the essays of other competitors, receiving honorable mention, to be published also, at the discretion of the Board of Control; and no change shall be made in the text of any competitive essay, published in the Proceedings of the Institute, after it leaves the hands of the Board.

4. Any essay not having received honorable mention, may be published also, at the discretion of the Board of Control, but only with the consent of the author.

5. The essay is limited to fifty (50) printed pages of the Proceedings of the Institute.

6. All essays submitted must be either type-written or copied in a clear and legible hand.

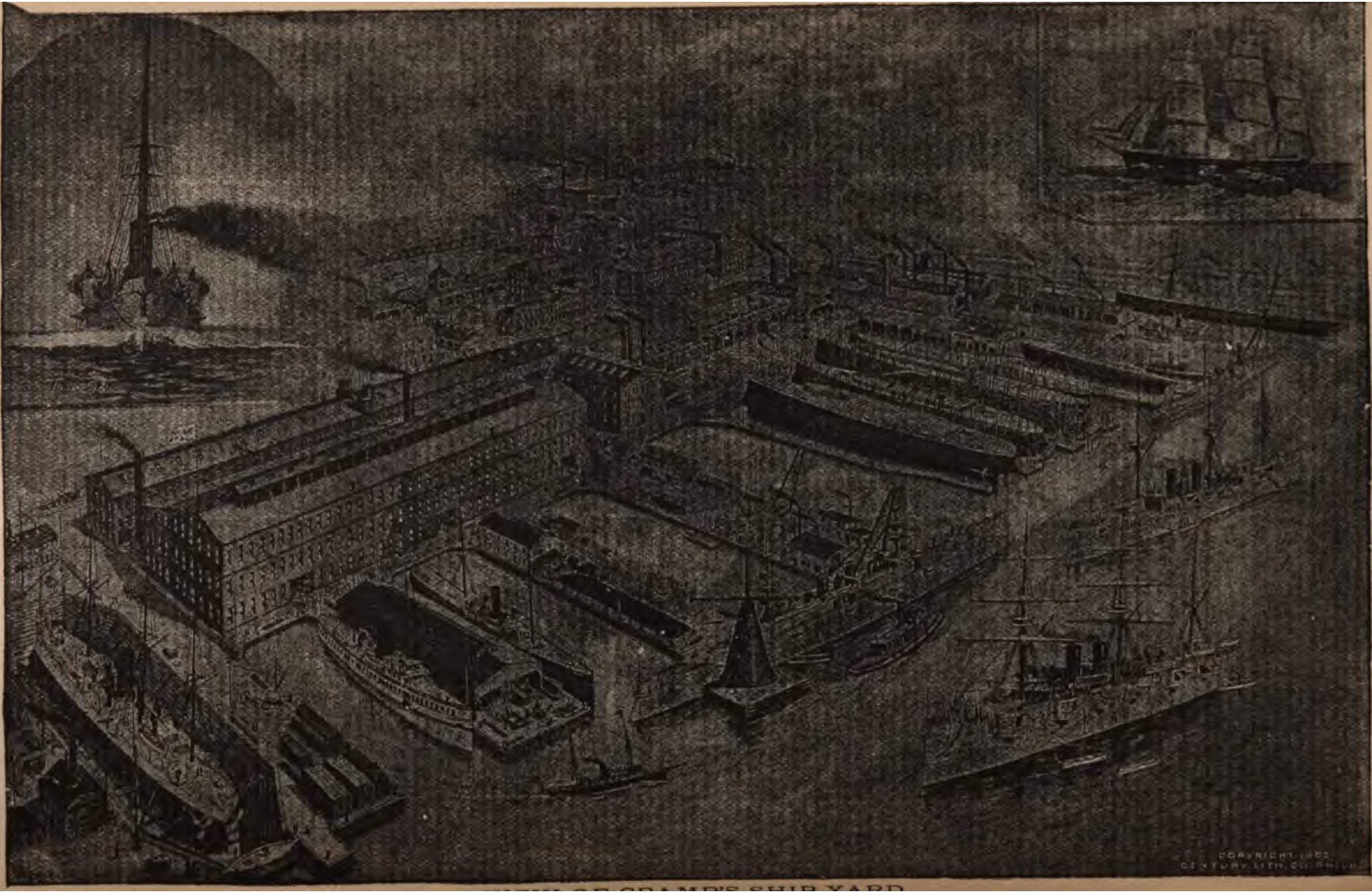
7. The successful competitor will be made a Life Member of the Institute.

8. In the event of the Prize being awarded to the winner of a previous year, a gold clasp, suitably engraved, will be given in lieu of a gold medal.

By direction of the Board of Control.

H. G. Dresel,
Lieut., U. S. N., Secretary and Treasurer.

Annapolis, Md., *January 1, 1897.*



OF CRAMP'S SHIP YARD

NOTICE.

The U. S. Naval Institute was established in 1873, having for its object the advancement of professional and scientific knowledge in the Navy. It now enters upon its twenty-fifth year of existence, trusting as heretofore for its support to the officers and friends of the Navy. The members of the Board of Control cordially invite the co-operation and aid of their brother officers and others interested in the Navy, in furtherance of the aims of the Institute, by the contribution of papers and communications upon subjects of interest to the naval profession, as well as by personal support and influence.

On the subject of membership the Constitution reads as follows:

ARTICLE VII.

Sec. 1. The Institute shall consist of regular, life, honorary and associate members.

Sec. 2. Officers of the Navy, Marine Corps, and all civil officers attached to the Naval Service, shall be entitled to become regular or life members, without ballot, on payment of dues or fee to the Secretary and Treasurer, or to the Corresponding Secretary of a Branch. Members who resign from the Navy subsequent to joining the Institute will be regarded as belonging to the class described in this Section.

Sec. 3. The Prize Essayist of each year shall be a life member without payment of fee.

Sec. 4. Honorary members shall be selected from distinguished Naval and Military Officers, and from eminent men of learning in civil life. The Secretary of the Navy shall be, *ex officio*, an honorary member. Their number shall not exceed thirty (30). Nominations for honorary members must be favorably reported by the Board of Control, and a vote equal to one-half the number of regular and life members, given by proxy or presence, shall be cast, a majority electing.

Sec. 5. Associate members shall be elected from officers of the Army, Revenue Marine, foreign officers of the Naval and Military professions, and from persons in civil life who may be interested in the purposes of the Institute.

Sec. 6. Those entitled to become associate members may be elected life members, provided that the number not officially connected with the Navy and Marine Corps shall not at any time exceed one hundred (100).

Sec. 7. Associate members and life members, other than those entitled to regular membership, shall be elected as follows: Nominations shall be made in writing to the Secretary and Treasurer, with the name of the member making them, and such nominations shall be submitted to the Board of Control, and, if their report be favorable, the Secretary and Treasurer shall make known the result at the next meeting of the Institute, and a vote shall then be taken, a majority of votes cast by members present electing.

The Proceedings are published quarterly, and may be obtained by non-members upon application to the Secretary and Treasurer at Annapolis, Md. Inventors of articles connected with the naval profession will be afforded an opportunity of exhibiting and explaining their inventions. A description of such inventions as may be deemed by the Board of Control of use to the service will be published in the Proceedings.

Single copies of the Proceedings, $1.00. Back numbers and complete sets can be obtained by applying to the Secretary and Treasurer, Annapolis, Md.

Annual subscriptions for non-members, $3.50. Annual dues for members and associate members, $3.00. Life membership fee, $30.00.

All letters should be addressed to Secretary and Treasurer, U. S. Naval Institute, Annapolis, Md., and all checks, drafts and money orders should be made payable to his order, without using the name of that officer.